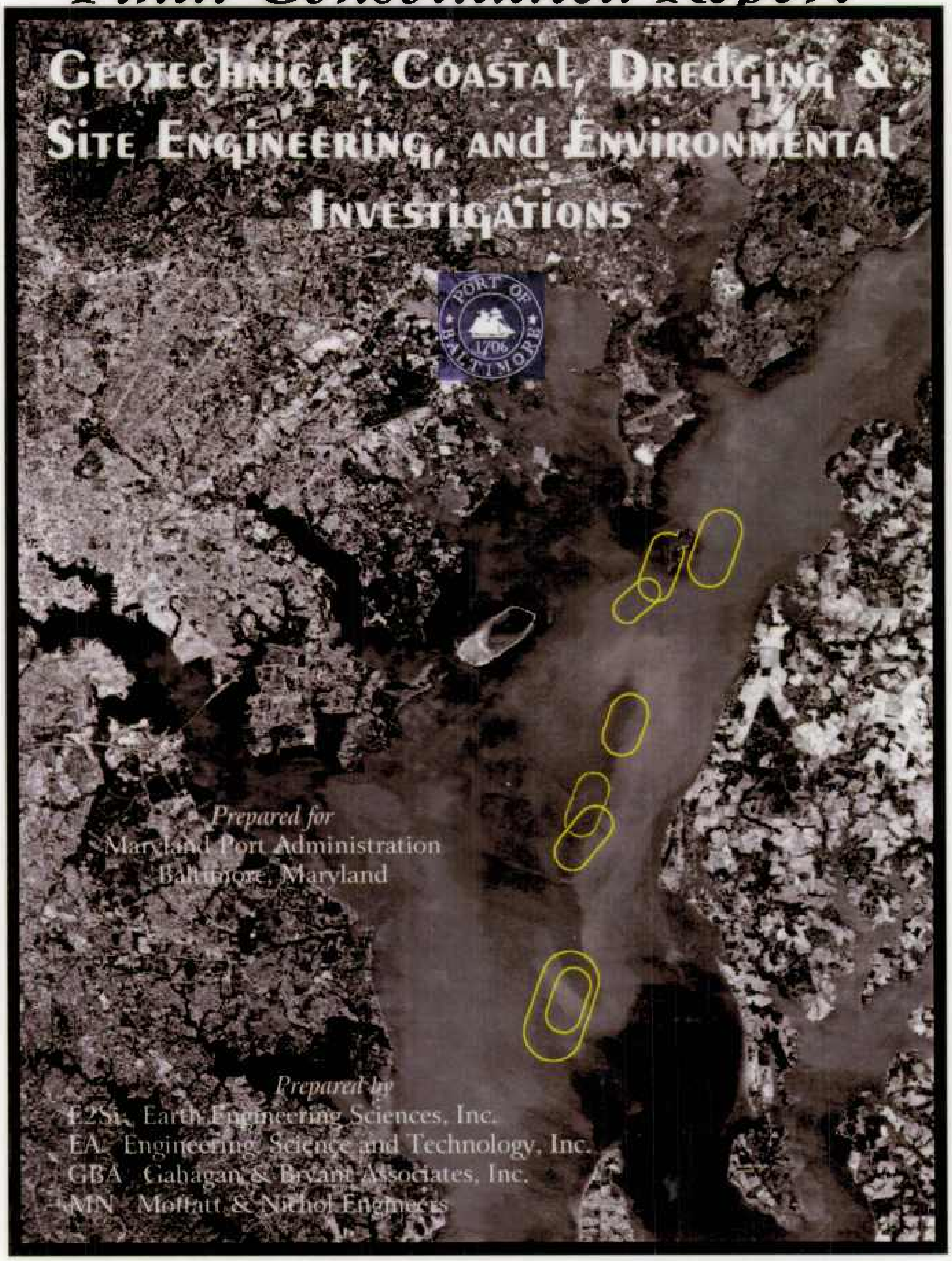
Final Consolidated Report



Geotechnical, Coastal, Dredging & Site Engineering, and Environmental Investigations

Prepared for
Maryland Port Administration
Baltimore, Maryland

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EXECUTIVE SUMMARY

Introduction

This report describes preliminary technical assessments of four general areas in the Upper Chesapeake Bay that were previously identified as possible locations for a dredged material containment island. Within the four general study areas, five sites and two sub-sites were evaluated (see Figure ES-1). The overall results of the study are summarized in Table ES-1. This summary outlines how the study was conducted and what the results mean. The report details how the results were obtained.

Study Objectives

The Prefeasibility Study for Upper Bay Island Placement Sites was coordinated by the Maryland Port Administration (MPA) in response to a directive from the Maryland General Assembly (SOM, 1996). The purpose was to perform preliminary technical assessments of four areas in the Upper Chesapeake Bay previously identified as possible locations for a dredged material containment island. The target capacity is 80 million cubic yards (mcy), which would meet the Port of Baltimore's projected navigational dredging needs for approximately 20 years. This study is in response to the long-term capacity element in the Governor's Strategic Plan for Dredged Material Management.

The four general areas targeted in the study were identified previously by the MPA based on input from participants in the Dredging Needs and Placement Options Program (DNPOP), a cooperative effort that includes working groups representing federal, state, and local governments as well as vested interest groups and members of the public. The four study areas were selected by the Upper Bay Enhancement Phase II Working Group (BEPWG) based on pre-existing information and the professional experience and judgment of the participants. It was concluded that the region between Pooles Island and the Chesapeake Bay Bridge would be the best location for the placement site.

Study Design

The prefeasibility study focused primarily on site designs that could hold approximately 80 mcy of dredged material, yielding a net site operational life of 20 years (assuming an annual placement rate of 4 mcy). Within the four general study areas, five sites and two sub-sites were evaluated in the prefeasibility study which was coordinated by the MPA and performed by four consultants. Four technical assessments (geotechnical, coastal, dredging/site engineering, and environmental) of the study areas were conducted from June through October 1997. Depending on the issues under investigation, the studies concentrated on slightly different regions and acreage, focusing primarily on sites 1, 2, 3, 4A, and 4B. (Some of the results for sites 3 and 4B are generally applicable to sub-sites 3-S and 4B-R, respectively.) Sub-sites 3-S and 4B-R were evaluated separately when appropriate, as in the overall cost analysis. A new potential alignment for Site 2 was identified later in the study; however, it was not carried through the studies due to a lack of sufficient information.

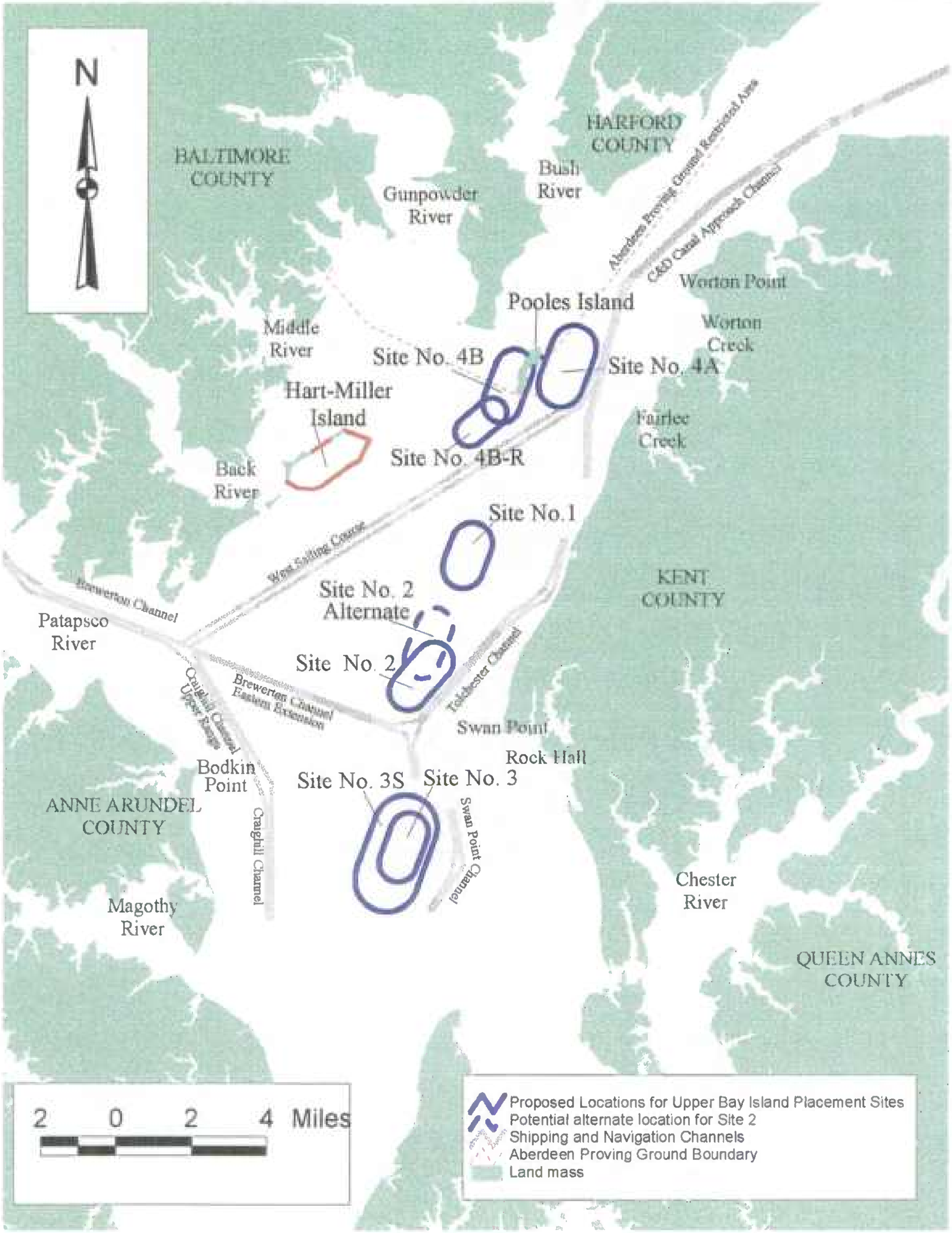

Figure ES-1. Proposed locations for upper Bay island placement sites.
All sites sized to reflect 80 mcy capacity. Environmental investigation considered 2,000 acres from centerpoint of sites depicted here.

Table ES-1. Comparison of Sites Based on Costs and Environmental Effects[A]

SITE	COSTS (In 1997 $)			ENVIRONMENTAL EFFECTS[B]
	Initial Construction	*Site Development*	*Total*	
Site 1	$62 million $0.77/yd³	$88 million $1.10/yd³	$552 million $6.91/yd³	**moderate** environmental effect; site may have been location of ancient island; site has higher water quality and fisheries value than many other sites
Site 2	$184 million $2.30/yd³	$210 million $2.63/ yd³	$669 million $8.37/yd³	**low** environmental effect; existing benthic communities are degraded; site would have least effect on recreational and commercial fisheries; site is adjacent to channel but might be shifted to the northwest to reduce navigational effects, while providing sand for dike construction
Site 3	$307 million $3.82/ yd³	$332 million $4.13/ yd³	$806 million $10.05/yd³	**low** environmental effect; deepest site; existing benthic communities are degraded; site supports some commercial harvests; oyster bar nearby
Subsite 3-S (special case)[C]	$89 million $1.12/ yd³	$300 million $3.76/ yd³	$572 million $7.17/ yd³	**low** environmental effect; site is a submerged island with potential for future beneficial use as fish habitat or oyster bar; site has large acreage unless reduced in area and combined with second site; permits needed for open-water placement and capping
Site 4A[D]	$283 million $3.51/ yd³	$311 million $3.86/ yd³	$766 million $9.52/yd³	**high** environmental effect; site is fish nursery and commercial harvest area; near spawning habitats; UXO[E] could be present, requiring potentially costly screening and removal; changes in current velocity and salinity may be the greatest at this site; potential navigational effects
Site 4B[D]	$165 million $2.06/ yd³	$192 million $2.40/ yd³	$663 million $8.28/ yd³	**very high** environmental effect; site overlaps Aberdeen Proving Ground and includes Pooles Island, which contains historical and archeological resources; a wide variety of habitat types and historic and cultural resources are located within or adjacent to the site; UXO[E] should be anticipated, requiring costly screening and removal
Subsite 4B-R (special case)[D]	$173 million $4.31/ yd³	$187 million $4.68/ yd³	$423 million $10.56/ yd³	**moderate** to **high** environmental effect; site is detached from Pooles Island and Aberdeen Proving Ground; site offers only half of target capacity and would need to be combined with second, half-capacity site; UXO[E] could be present, requiring potentially costly screening and removal

NOTES:

[A] Results presented are summarized based on cost and environmental analysis conducted by GBA (1997) and EA (1997).

[B] The environmental evaluation is based on a screening-level analysis of the expected effects of a dredged material containment island on 20 natural-resource and human-environment (e.g., navigational) parameters at each site.

[C] Costs for Site 3-S include capping but no dike raising.

[D] Initial construction costs for sites 4A, 4B, and 4B-R include the investigation and removal of unexploded ordnance.

[E] UXO=Unexploded ordnance.

The geotechnical investigation by Earth Engineering & Sciences, Inc. (E2Si, 1997) included a review of the geology of the area and existing acoustic and boring data, as well as new boring data obtained as part of the prefeasibility study, as a basis for evaluating both the foundation and available borrow material (i.e., sand) for dike construction. Five to eight borings, varying in depth from 40 to 80 ft (below the mud line), and five electric cone penetration tests, varying in depth from 23 to 86 ft (below the mud line), were drilled at each of sites 1, 2, and 3. Two borings were drilled at sites 4A and 4B to 20 ft depths, due to the possible presence of unexploded ordnance (UXO) resulting from nearby weapons tests at the U.S. Army's Aberdeen Proving Ground (APG). Laboratory tests were performed to determine the stress history, strength characteristics, and index properties of various soil strata at each site. Slope stability analyses were conducted for various cross-sections of containment dikes; based on the results, dike sections were designed for hard and soft foundations.

The coastal engineering investigation by Moffatt & Nichol Engineers (M&N, 1997) included a review of relevant data on bathymetry and topography, wind conditions, and water levels as a basis for estimating wave conditions for the sites. Relevant data on currents and sediment characteristics were also reviewed with regard to the effects on dike construction. The hydrodynamic effects of a containment island on currents, residence times, salinity and sedimentation were modeled and assessed using a 2-D computer simulation program developed by the U.S. Army Corps of Engineers (USACE). Dike alignments and minimum initial dike elevations were determined based on the results of the coastal evaluation. The coastal protection elements were designed for the perimeter dikes for a 35-year storm return period.

The dredging and site engineering investigation by Gahagan & Bryant Associates, Inc. (GBA, 1997) included a review of site screening criteria used in several previous studies of dredged material placement sites in the Chesapeake Bay. Information on site characteristics was collected from several sources and digitized to produce a series of base maps for the entire study region and each individual site. The sites were assessed using both existing data and the results of new field investigations. A range of surface areas and dike heights were investigated initially to develop relationships among site areas, dike heights, site capacity, and site operational life. Specific sites were then designed to provide an operational life of 20 years (or a capacity of 80 mcy). Total costs were calculated as the sum of site development costs and maintenance dredging costs. Based on these numbers, a discounted present worth cost estimate was also generated for planning purposes.

The environmental investigation by EA Engineering, Science, and Technology, Inc. (EA, 1997) screened an area of approximately 2,000 acres at each site using a compilation of parameters identified in previous studies. Two-thousand acres were targeted so that the environmental analysis would support a variety of potential island and dike configurations and provide a conservative evaluation of the resources in the placement area. EA's investigation relied on existing resource information, which was plentiful for the areas around Pooles Island (sites 4A and 4B) but scarce for the open-water areas (sites 1, 2, and 3). Limited field surveys were conducted to characterize habitat quality and acquire comparable information for all five original sites as a basis for evaluating various aquatic resources. Each site was evaluated with respect to 20 natural-resource and human-environment parameters, which were chosen to reflect the concerns of the Chesapeake Bay community and the Working Group supporting the study. A base evaluation was assigned to each parameter for each site based on the existing condition of the resource(s) considered. The base evaluation was also assigned a weighting factor to account for differences in the relative importance of various resources on a regional basis. The sites were then compared based on the weighted evaluations.

During the study process, the consultants' data, analytical approaches, and draft reports were shared with the Working Group supporting the study. The Working Group, part of the DNPOP process, was coordinated for the MPA by the Maryland Environmental Service (MES). The Working Group expressed particular concerns about the hydrodynamic effects, potential effects on living resources, assessment categories, weighting factors, UXO, site characterization methods, and the environmental sensitivities of the Pooles Island area. Based on input from the Working Group, a number of changes were made in the study, principally the decision to perform 3-D modeling of the effects of containment islands on tidal hydrodynamics, as an extension of the prefeasibility study.

Cost Analysis

The total cost of developing and using any site as a containment island is affected directly or indirectly by many factors, including the suitability of bottom material as foundation for a dike, environmental sensitivity of the area, hydrodynamic effects of a containment facility, and distances over which dredged material must be transported for placement. For example, the foundation quality and hydrodynamics directly affect dike construction costs. Environmental sensitivity could affect site construction costs if mitigation projects are required, or if permitting requires intensive environmental investigation. The distances over which dredged material must be transported directly affects the cost of filling the containment facility.

Total costs for each site were estimated based on site development costs (including initial construction of dikes and spillways, annual site management and monitoring, and dike-raising costs) and the costs of dredging and transporting fill material throughout the operational life of the site. Depending on how a project is implemented, the costs borne by the project sponsor(s) may be best represented by site development costs.

Site layouts were determined based on geographical, physical, biological, environmental, geotechnical, and other considerations (e.g., aesthetics). Site designs were determined based on surface area, dike elevations, rock protection, potential borrow sources, site access/facilities, and site capacity and operational life. Initially, a range of surface areas (500; 1,000; 1,500; and 2,000 acres) and dike heights (10, 20, 30, and 40 ft) were investigated to develop relationships among site areas, dike heights, site capacity, and operational life. Then, based on a target site capacity of 80 mcy (or an operational life of 20 years), costs were estimated for two designs at each site. The first design assumed no consolidation of the dike foundation. The second design, which featured a smaller surface area and higher dike, assumed some increase in dike foundation strength as a result of consolidation. Only one design was possible at Site 3-S.

Table ES-2 shows the initial construction cost, site development cost, and total cost for the least expensive design (i.e., the design with the smaller surface area) for each site. Sites 1 and 3-S have the lowest initial construction costs and total costs. Site 3-S is only slightly more expensive than Site 1, even after accounting for periodic renourishment of a sand cap after the site is filled. However, before Site 3-S could be used, a permit would need to be obtained for confined open-water placement, and various issues related to underwater capping (e.g., permitting requirements, monitoring, potential sediment resuspension during storms, interim caps or site closure) would need to be addressed.

Sites 2 and 4B have higher initial and total costs. Site 2 has weak foundation soils because it overlaps an area formerly used for the placement of dredged material. This site might be shifted to the northwest, potentially to a firmer foundation that would contain sand for dike construction. Therefore, it is recommended that additional data be collected along this location to evaluate the bottom characteristics. Note that this shift would also move Site 2 further away from the adjacent navigation channel. Sites 1 and 4B both offer good foundations consisting of stiff clays and sands, and good borrow conditions (i.e., sand available at the site for dike construction). However, the use of sand from Site 4B could require the removal and disposal of UXO, at considerable expense.

Sites 3 and 4A are the most expensive choices, primarily because of weak foundation soils and, as a result, high initial construction costs. The costs for Site 4B-R, which are relatively high per cubic yard of capacity, need to be considered separately because this site provides only half of the target capacity and would need to be combined with a second, half-capacity site.

The identification and removal of UXO, expected to be present at sites 4A, 4B, and 4B-R, are included in the cost analysis. There is considerable uncertainty associated with the estimated costs of screening for, and removing, underwater UXO. Also included in the analysis are the costs of undercutting inadequate foundation soils at sites 2, 3, 4A, 4B, and 4B-R, and replacing them with sand. Costs are also presented in constant 1997 dollars versus discounted present worth 1997 dollars (Figures ES-2 and ES-3) for the sake of comparison.

Environmental Analysis

The environmental analysis was based on screening-level information. Each site was evaluated based on the expected effects of a containment island on 20 natural-resource and human-environment parameters, including water quality; salinity; hydrodynamic effects; sediment quality; benthic community and habitat; recreational fishery; commercial fish and shellfish; finfish spawning and rearing habitat; larval transport; submerged aquatic vegetation and shallow-water habitat; waterfowl

Table ES-2 Alternative Analysis - Cost Matrix (values in constant 1997 dollars)

Site Desig-nation*	Net Site Capacity (Mcy)	Site Life (Years)	INITIAL CONSTRUCTION COSTS		Annual Costs	Dike Raising	SITE DEVELOPMENT COSTS		Dredging/Transport & Placement Costs		TOTAL COSTS	
			$ Million	$ / CY	$ Million	$ Million	$ Million	$ / CY	$ Million	$ / CY	$ Million	$ / CY
1 - 1	80	20	70	0.88	24.6	2.67	98	1.23	464	5.82	562	7.05
1 - 2	80	20	62	0.77	22.2	4.31	88	1.10	464	5.81	552	6.91
2 - 1	80	20	199	2.48	26.0	0.51	226	2.81	459	5.73	685	8.54
2 - 2	80	20	184	2.30	24.9	1.20	210	2.63	459	5.74	669	8.37
3 - 1	80	20	320	4.01	24.8	0.32	345	4.32	474	5.94	820	10.26
3 - 2	80	20	307	3.82	24.0	0.99	332	4.13	474	5.92	806	10.05
3-S	80	20	89	1.12	12.1	199 **	300	3.76	272	3.41	572	7.17
4A - 1	80	20	316	3.94	28.2	0.76	345	4.30	455	5.67	800	9.97
4A - 2	80	20	283	3.51	26.8	1.50	311	3.86	455	5.66	766	9.52
4B - 1	80	20	213	2.67	25.4	2.91	241	3.02	471	5.90	712	8.93
4B - 2	80	20	165	2.06	22.7	4.61	192	2.40	471	5.88	663	8.28
*** 4B - R - 1	40	10	186	4.64	11.8	0.41	198	4.95	235	5.88	433	10.82
*** 4B - R - 2	40	10	173	4.31	11.3	3.46	187	4.68	235	5.88	423	10.56

Notes:

1. Initial Construction Costs include dike construction, spillways and other facilities.
2. Annual Costs include site management, O&M, material drying, and site monitoring for the operational life of the site.
3. Site Development Costs include initial construction costs, annual costs, and dike raising costs.
4. Dredging Costs include dredging, transport and placement of maintenance material for the operational life of the site.
5. Total Alternative Costs include site development costs plus maintenance dredging costs for the operational life of the site.
6. (*) Each site includes two alternatives, one for each of two dike heights (e.g.: 1 - 1 & 1 - 2). The first alternative assumes no long-term gain in foundation strength due to consolidation, while the second alternative does assume such a gain in foundation strength.
7. (**) Site 3-S has no dike raising costs; however, site development costs for site 3-S include costs for capping, which are shown here.
8. (***) Note that sites 4B - R - 1 and 4B - R - 2 would have to be combined with another smaller site option in order to meet the projected MPA dredging demand.
9. All alternatives except 1 - 1, 1 - 2 and 3 - S include foundation undercut and replacement with sand fill, which is accounted for in the initial construction costs.
10. Initial construction costs for sites 4A, 4B and 4B - R also include the costs for investigation and removal of UXO's.
11. Annual site maintenance costs after the operational life of the site are not considered in this analysis.
12. Sites 4A, 4B and 4B-R includes costs for UXO investigation, removal and storage at the APG facility at an estimated cost of $80,000/acre for 10 ft sweeping depths under the dike foot print and borrow sources. At other areas, the cost was estimated to be $20,000/acre for a 2 ft surficial sweep.

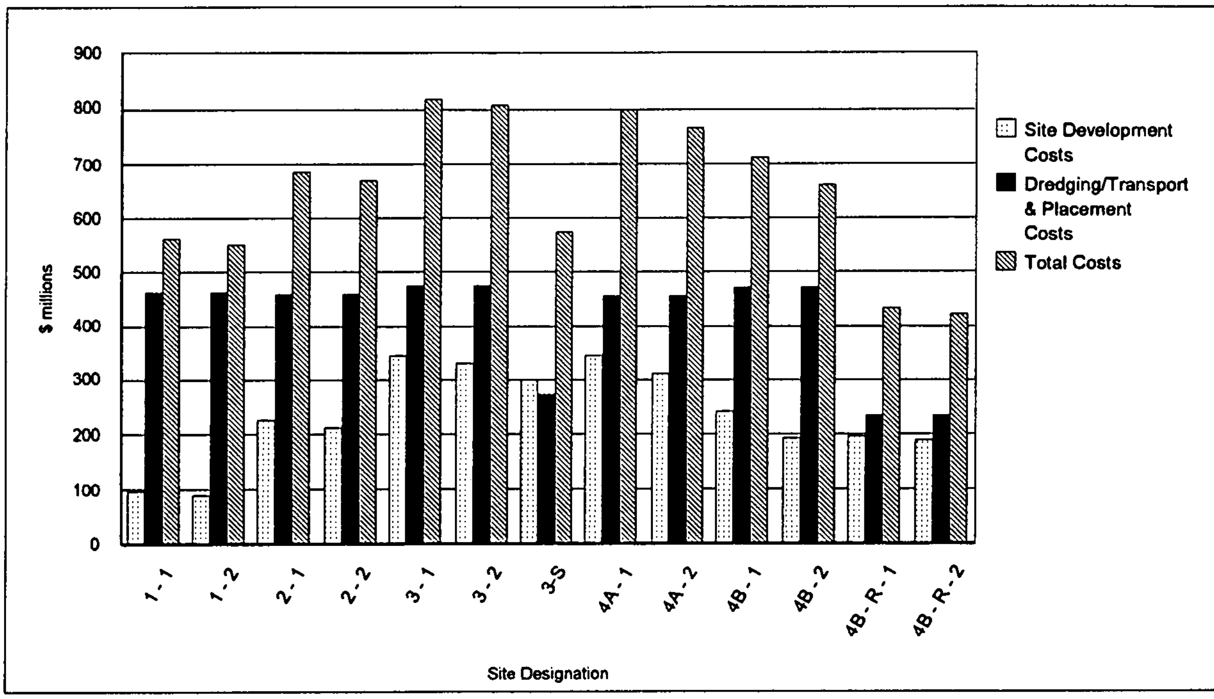

Figure ES-2. Comparison of Site Costs (in constant 1997 Dollars) for Various Alternatives

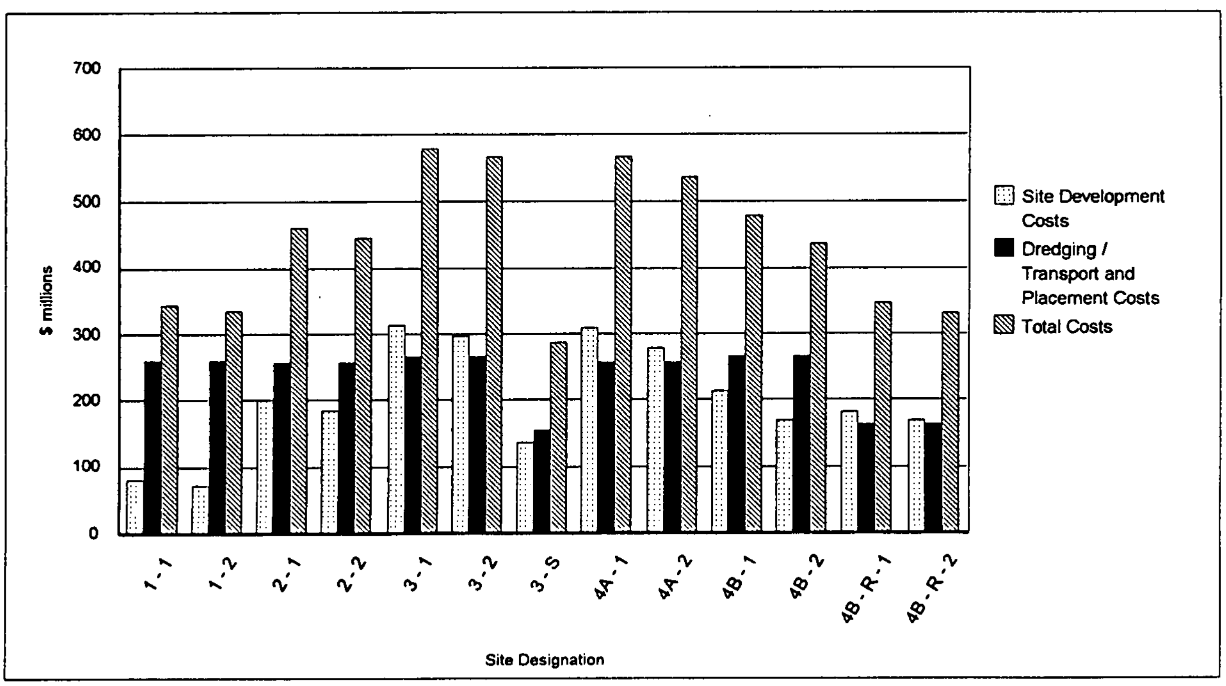

Figure ES-3. Comparison of Present Worth Site Costs (in discounted 1997 Dollars) for Various Alternatives

use; tidal wetlands; terrestrial habitat and wildlife; rare, threatened, and endangered species; recreational value; historical resources; aesthetics and noise; fossil shell mining; UXO and Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) liability; and navigation.

Based on existing information and limited field surveys, each parameter was assigned a base evaluation of +1, 0, or -1 for each site. If a resource was already degraded or little or no immediate impact was expected as a result of island creation, then the parameter was assigned a base evaluation of +1. If a resource was of high quality and immediate negative impacts were expected, then the parameter was assigned a base evaluation of -1. If the available information was ambiguous or insufficient to make a judgment, then the parameter was assigned a base evaluation of 0. Each parameter was assigned a weighting factor based on the perceived importance of various resources on a regional basis. The weighting factors were based on those derived in the draft 1989 Port of Baltimore Dredged Material Management Master Plan, the professional judgment of the EA team, and input from MES and the Working Group supporting the pre-feasibility study.

For each site, the base evaluations for all parameters were summed. Weighting affected the sums for individual sites but had no effect on the overall comparison of sites. The sum for each site reflects the balance of trade-offs, or changes in existing conditions, with respect to the various environmental parameters. Table ES-3 provides the weighted evaluations for each parameter at each site.

In general, the southern sites are less sensitive environmentally (i.e., they received the highest scores) than those located to the north (4A, 4B, and 4B-R which received the lowest scores). A containment island at sites 2, 3, and 3-S would be expected to involve fewer environmental trade-offs, or have less environmental effect, relative to the other sites. (Sites 3 and 3-S were considered to be identical for purposes of the environmental analysis.) These sites lie entirely within deep open water and, if developed, would have no effect on terrestrial resources. Historical and recent data suggest that the benthic environments in these areas are already stressed. In addition, once filled and closed, Site 3-S could potentially offer a beneficial use as a fish habitat or oyster bar.

Site 2 is located adjacent to a shipping channel, but the potential effects on navigation could be reduced by shifting the site to the northwest (Figure ES-1). As noted in the previous section, it is recommended that additional bottom data be collected to evaluate this alternative, which might also provide a firmer foundation and sand for dike construction.

Site 1 would involve moderate environmental trade-offs, reflecting the higher water quality and fisheries values for that area in comparison to sites 2, 3, and 3-S. Site 1 has geological features that suggest it may have been the location of an ancient island.

Sites 4A, 4B, and 4B-R would be expected to involve more environmental trade-offs relative to the other sites studied. Based on the screening-level information, Sites 4A and 4B are the most

Table ES-3 Upper Bay Island placement sites: Environmental effects on existing conditions ranking matrix—weighted evaluations

FACTOR	Weighting Factor	PROPOSED SITES					
		SITE NO. 1	SITE NO. 2	SITE NO. 3/3S [a]	SITE NO. 4A	SITE NO. 4B	SITE NO. 4B-R [b]
Water Quality (wq)	2	-2	2	2	-2	-2	-2
Salinity	4	0	0	0	0	0	0
Hydrodynamic effects (ero*4)	4	4	4	4	-4	-4	-4
Sediment Quality (sub)	2	2	2	0	0	2	2
Benthic Community and Habitat (sub + wq/2)	2	-2	2	2	-2	-2	-2
Recreational Fishery (fsh or slf)	4	-4	4	0	-4	-4	4
Commercial Fish and Shellfish (slf)	4	-4	-4	-4	-4	-4	-4
Finfish Spawning and Rearing Habitat	4	0	4	4	-4	-4	-4
Larval Transport	6	0	0	0	0	0	0
SAV and Shallow Water Habitat (sav)	4	4	4	4	4	-4	4
Waterfowl Use (fwl)	1	1	1	1	-1	-1	1
Tidal Wetlands (tw)	3	3	3	3	3	-3	0
Terrestrial Habitat and Wildlife (for)	2	2	2	2	2	-2	0
RTE Species(rte)	5 (c)	-5	-5	-5	-5	-10	-5
Recreational Value (fsh/2)	2	0	2	0	-2	-2	-2
Historic Resources (arc + hst/2)	4	4	4	4	4	-4	4
Aesthetics and Noise (pop)	2	0	2	2	2	2	2
Fossil Shell Mining	2	-2	2	2	-2	2	2
CERCLA & UXO potential	5	5	5	5	-5	-5	-5
Navigation	4	4	-4	4	-4	-4	-4
TOTAL		10	30	30	-24	-49	-13
Sum of weights (d)	66	54	56	50	56	56	54
Weighted Average		0.18	0.54	0.60	-0.42	-0.88	-0.24

(a) Has a potentially significant beneficial use
(b) Small site only: 40 MCY (+/-) capacity
(c) 5 for each endangered species potentially present
(d) Sum of weighting factors including only parameters that don't have shaded zeros (lack of information).
Key for Weighted Evaluation: Weighting Factor x Base Evaluation = Weighted Evaluation. Weights (and variables) derived from the Port of Baltimore Dredged Material Management Draft Master Plan (1989). Weighted average = TOTAL score/sum of weights.
Key for Base Evaluation: +1 = resource already impacted or no impact expected; -1= Projected impact to resource; 0 = not enough conclusive evidence to make a definitive score or evidence is ambiguous (shaded) or somewhat affected already/little further impact expected.
Construction at Sites 4A & 4B may borrow material from Site No. 1, which would impact the benthic community and fish habitat at that site.
Resource agents consider effects to larval transport and salinity to be the most importatant issues for island construction in the upper Bay.

environmentally sensitive. Both sites have high values for fisheries and recreation as well as the potential for UXO and CERCLA liability. The greatest changes in current velocity and salinity would be expected at Site 4A. The greatest overall environmental effects would be expected at Site 4B because of the potential for protected species and the wide variety of habitat types and historic and cultural resources within or adjacent to the site. Site 4B-R lacks the terrestrial, natural, and historical resources associated with Pooles Island, but is likely to contain UXO.

This phase of the prefeasibility study used 2-D hydrodynamic modeling to evaluate tidal flows at each site, both under existing conditions and with a simulated containment island. The 2-D model enabled the screening of most of the potential hydrodynamic effects of an island but was not complete at the time that some sections of this report were written. When the 2-D modeling was completed, it indicated only subtle differences were detected among the sites with respect to changes in current velocity, residence times, salinity, and dispersion of effluent from Hart-Miller Island. The environmental effects were not re-evaluated with respect to the modeling results because further hydrodynamic study may occur. Given the complexity of the Chesapeake Bay, the study team recommends 3-D modeling of all the sites to verify the 2-D results, clarify any ambiguities, and provide additional information concerning the effects on salinity, larval transport, oyster bars, and clam beds. The additional dimension in 3-D modeling is derived from varying water depths. This may prove to be especially important in the case of sites 2 and 4A, which are located adjacent to the deep-water shipping channels. Possible changes in tidal flows, channel currents, and storm waves due to the interaction of the islands with the channels represent unknown factors at this time. The modeling process is expected to take six months to a year. A technical subgroup devoted to the sole issue of 3-D modeling is currently evaluating the most appropriate 3-D model to be used along with the proper duration, tidal cycles, and time intervals. Potential environmental effects of the proposed islands will be re-evaluated when 3-D modeling is completed.

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LIST OF SYMBOLS AND ACRONYMS

ADCP	Acoustic Doppler Current Profiler
APG	Aberdeen Proving Ground
BCOE	Baltimore Corps of Engineers
B-IBI	Benthic Index of Biotic Integrity
BWA	Baltimore Watermen's Association
BWI	Baltimore-Washington International
c	Cohesion
C&D	Chesapeake & Delaware
CBP	Chesapeake Bay Program
CBPWQM	Chesapeake Bay Program Water Quality Monitoring
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (also referred to as "Superfund")
CPT	Cone Penetrometer Test
CPUE	Catch-Per-Unit-Effort
CTD	Conductivity, Temperature and Depth
CZMA	Coastal Zone Management Act
DMCI	Dredged Material Containment Island
DNPOP	Dredging Needs and Placement Options Program
DNR	Department of Natural Resources
DO	Dissolved Oxygen
d_{50}/D_{50}	Median grain size of the sample
E	East
EA	EA Engineering, Science & Technology, Inc
EIS	Environmental Impact Statement
El	Elevation
EM	Engineering Manual
E2Si	Earth Engineering & Sciences, Inc
FEMA	Federal Emergency Management Agency
FS	Factor of Safety
GBA	Gahagan and Bryant Associates
GIS	Geographic Information System
GISD	Geographical Information System Database
GPS	Global Positioning System
L	Liter
LF	Linear foot
LL	Liquid Limit
MCBA	Maryland Charter Boat Association
mcy	Million cubic yards
MDE	Maryland Department of the Environment

LIST OF SYMBOLS AND ACRONYMS (continued)

MDNR	Maryland Department of Natural Resources
MES	Maryland Environmental Service
mg/kg	milligram per killigram
MGS	Maryland Geological Survey
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLW	Mean Low Water
M&N	Moffatt & Nichol Engineers
MPA	Maryland Port Administration
MTL	Mean Tide Level
MWA	Maryland Watermens Association
N	North
N	Standard Penetration Resistance
NE	Northeast
NEPA	National Environmental Policy Act of 1969
nm	Nautical Mile
NMFS	National Marine Fisheries Service
NOEL	No Observed Effects Level
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPL	National Priority List
NTU	Nephelometric Turbidity Units
NW	Northwest
O&M	Operation and Maintenance
Pc	Preconsolidation Pressure
PCOE	Philadelphia District Corps of Engineers
PEL	Probable Effects Level
PI	Plasticity Index
PL	Plastic Limit
ppm	Parts per million
ppt	Parts per trillion
psf	Pounds per square foot
QA/QC	Quality Assurance/Quality Control
RGI	Restoration Goal Index
RMA	Resource Management Associates
RP	Return Period
RTE	Rare, Threatened, and Endangered
S	South

LIST OF SYMBOLS AND ACRONYMS (continued)

SE	Southeast
SAV	Submerged Aquatic Vegetation
SHPO	State Historic Preservation Office
SSW	South-Southwest
SW	Southwest
TARSA	Technical and Regulatory Services Administration
TSS	Total Suspended Solids
UMD	University of Maryland
UMD-HL	University of Maryland, Horn Point Laboratory
USACE	United States Army Corps of Engineers
USWFS	U.S. Fish and Wildlife Service
UXO	Unexploded ordnance
VIMS	Virginia Institute of Marine Science
W	West
WC	Water Content
WES	Waterways Experiment Station
WOH	Weight of Hammer
WOR	Weight of Rods
WRDA	Water Resources Development Act
ϕ	Angle of Internal Failure

1.0 INTRODUCTION

1.1 Project Objective

The objective of this project was to conduct a prefeasibility investigation for the construction of a long-term dredged material island placement site in the Upper Chesapeake Bay. The investigation focused on facilities that, at a minimum, would be capable of handling approximately 80 million cubic yards (mcy) of dredged material from the Baltimore Harbor outer navigation channels over a period of twenty years. Specific areas to be evaluated as part of this investigation were determined based on the results of the area identification, preliminary screening, and technical rankings. This preliminary work was performed by the Bay Enhancement Phase II Working Group (BEPWG, 1996), which was part of the Maryland Port Administration (MPA) sponsored Dredging Needs and Placement Options Program (DNPOP). Accordingly, four study areas selected with the assistance of the Working Group were evaluated.

1.2 Project History and Description

The Port of Baltimore is managed by the MPA, which is a part of the State of Maryland, Department of Transportation. The Port is located on a 35-square mile area of the Patapsco River and its tributaries, approximately 12 miles northwest of the Chesapeake Bay Bridge (USACE, 1997a). The navigation channels of the port extend from Baltimore, Maryland, on the Patapsco River, 150 nm through the Chesapeake Bay into the Atlantic Ocean at Cape Henry, and 113 nm through the Chesapeake & Delaware (C&D) Canal, Delaware River, and Delaware Bay into the Atlantic Ocean. Baltimore Harbor navigation channels can be broadly classified into three categories:

- *Inner Harbor Channels* - which includes Northwest Channel, East Channel, Ferry Bar Channel, Fort McHenry Channel, Curtis Bay Channel, and Brewerton Channel.
- *Outer Harbor Channels* - which includes C&D Canal and Approach Channel, Tolchester Channel, Swan Point Channel, Brewerton Extension Channel, Craighill Upper Range Channel, Craighill Channel, and Craighill Entrance Channel.
- *Virginia Channels* - which includes Rappahannock Shoal Channel, York Spit Channel, and Cape Henry Channel.

Maintenance and improvement of these channels, coupled with the low availability of sites in which to place dredged materials, require proper management of existing sites and the development of long-term sites for placing material from future channel improvements. Currently, dredged material from the Virginia Channels is placed at facilities provided near Virginia by the Norfolk District, while the material from Inner Harbor Channels is placed at Hart-Miller Island (HMI) and CSX/Cox Creek Site (after reactivation). In order to satisfy future placement demands, the dikes at HMI were recently raised to +44 ft elevation (GBA, 1996; Hamons et al, 1997), and the CSX/Cox Creek Site will be reactivated soon (MPA, 1997). Material from C&D Canal is placed at upland sites, while some of the dredged material from the remaining Outer Harbor Channels is to be placed at Poplar Island so as to restore the island to its approximate 1847 footprint (MPA, 1997). However, there is a demand for a long-term placement site for handling dredged material from the Outer Channels. The MPA identifies the need for the upper Bay site to be approximately 4 mcy per year for a period of 20 years, resulting in a cumulative placement demand of 80 mcy. In order to meet this demand, four potential areas in the Upper Chesapeake Bay area were identified for detailed investigation (see Figure 1-1) with the help of the BEPWG (1996). The prefeasibility evaluation of the engineering and environmental aspects of constructing Upper Bay island placement sites was subsequently commissioned by MPA.

1.3 Previous Related Studies

Dredged material islands provide a beneficial, economical and environmentally attractive use of dredged material from ports and harbors (USACE, 1997; USACE, 1978; Landin, 1991; NRC, 1994; Herbich, 1992). Design aspects of such islands are well established (USACE, 1986; Machemehl, 1991; Mohan and Urso, 1997; and Palermo, 1995). Previous studies pertaining to planning and siting aspects of dredged material placement sites in the Baltimore Harbor area were reviewed to develop a database for the project. The following studies were reviewed: (i) HMI Siting Report, (ii) MPA Draft Master Plan, (iii) Poplar Island Design Report, (iv) DNPOP documents, and (v) BEPWG documents. In addition, a wide variety of environmental data were gathered from resource agencies, working group participants, and special interest groups.

1.3.1 HMI Siting

Green & Trident (1970) conducted a study for siting a diked dredged material placement site capable of handling an estimated 100 mcy from Baltimore Harbor channels. As part of their evaluation, they collected information on bathymetry and hydrodynamics of the Bay, sediment characteristics, water quality impacts, type of dredging/hauling equipment and costs, and potential beneficial uses of the dredged material. A socio-environmental analysis was prepared in order to evaluate potential impacts of dredging and placement on wildlife and commercial fisheries, shoreline contamination, and other natural resources. A list was prepared of potential sites including HMI, Black Marsh, Six-Seven-Nine Foot Knolls, Belvedere Shoal, and Patapsco River Mouth. These sites were evaluated using an econometric model involving unit costs and design analysis, together with socio-environmental factors. Based on the results, the study recommended that the placement facility be constructed at HMI due to economic and environmental advantages over the other sites screened. Details of this study can be obtained from Green & Trident (1970).

1.3.2 MPA Master Plan

MPA (1990) conducted a planning effort to identify management actions required for maintaining the navigable waterways of the Port of Baltimore. The planning process involved consideration of environmental, economic, engineering, institutional and other factors (MPA, 1990). Two advisory groups were formed as part of the process to give full consideration to the concerns of private maritime interests; federal, state and local governments; regulatory agencies; environmental groups and the general public. The study identified a shortfall of placement capacity for dredged material from C&D Canal Approaches, Inner Harbor and Outer Harbor channels. Several management options were evaluated, including modification/expansion of existing sites, creation of upland sites, land creation, open water placement, shoreline stabilization/wetland creation, material rehandling/reuse, borrow pit fill and cover, and ocean placement. The master plan used a set of environmental and economic exclusionary criteria to develop a list of potential alternatives. These criteria included tidal/non-tidal wetlands, submerged aquatic vegetation (SAV), fish spawning or nursery ground, shellfish area, waterfowl concentration area, forested area, rare, threatened or endangered species, water quality, substrate, erosion area, recharge area, hydrology, archaeology, history, population, and costs. A system for ranking the alternatives was developed by assigning a weighting factor to each of the screening criteria used for analysis. Alternatives were screened in two phases: (i) Phase I screening was used to narrow down the options to 162 sites for further evaluation, and (ii) Phase II screening was used to identify 31 potential options. Details of this study can be obtained from the draft MPA report (MPA, 1989).

1.3.3 Poplar Island Design Report

Poplar Island is located in the Chesapeake Bay and consists of a group of islands located northwest of the Tilgham Island near the confluence of the Chesapeake and Eastern bays. The Poplar Island Restoration Project would restore habitats lost through the erosion of Poplar Island by the beneficial use of dredged materials from the Bay approach channels to the Port of Baltimore. The plan will restore four remnant islands (North Poplar Island, Middle Poplar Island, South Central Poplar Island, and South Poplar Island) and will adjoin the island remnant known as Coaches Island. The project is to be carried out under the provisions of Water Resources Development Act 1996 and involves restoration of the islands (which have a current footprint of only 5 acres) to a pre-erosional 19th century area of about 1,000 acres, thereby creating new aquatic, intertidal wetland, and upland habitat for fish and wildlife. Restoration of Poplar Island is part of the State of Maryland's strategic plan for dredged material management, which provides a geographically balanced, environmentally sound, and cost-effective solution to the Port of Baltimore's dredging needs. The major objectives of the Poplar Island beneficial use project were as follows: (1) optimization of the volumetric capacity of the site for dredged material, (2) preparation of a cost-effective design within available funding, (3) restoration of Poplar Island to its 1847 footprint, (4) creation/restoration of desirable habitat, and (5) design of all aspects of the site in an environmentally acceptable manner.

The principal environmental concerns associated with the project include the following: (1) loss of open water, (2) changes in wave regime, (3) changes in tidal regime, (4) need for additional habitat, (5) impacts to adjacent islands, (6) impacts to oyster beds, and (7) restrictions on placement operations. To achieve the study objectives and address the afore mentioned concerns, planning and design studies considered several aspects of the alternative site layouts (GBA and M&N, 1995), including perimeter dike alignment and orientation, habitat development criteria, coastal and hydrodynamic aspects (wave, tide, and sedimentation modeling; dike slope protection; and optimized perimeter dike section), and dredging and site engineering aspects (site capacity and operational life, site construction methodology and schedule, dredged material placement modeling, site monitoring, and site management). Details of the planning aspects and habitat selection criteria are presented in GBA and M&N (1995), and EA (1995).

1.3.4 DNPOP Documents

It is estimated that approximately 4 mcy of material must be dredged from the navigation channels serving the Port of Baltimore to maintain them at existing depths and widths (MPA, 1996). The State of Maryland developed a strategic plan for dredged material management to provide a geographically balanced, environmentally sound, and cost-effective solution to the Port of Baltimore's dredging needs (SOM, 1996). The plan provides for dredged material placement capacity for the next 25 years and consists of the following element:

- Expand area used for open-water placement near Pooles Island, yielding an estimated additional capacity of 4.5 mcy over a period of 3 years.
- Raise north cell dike at HMI, yielding an estimated additional capacity of 30 mcy over a period of 12 years.
- Restore Poplar Island, yielding an estimated capacity of 38 mcy over a period of 20 years.
- Reactivate CSX/Cox Creek Containment Site, yielding an estimated capacity of 6 mcy over a period of 12 years.
- Establish new open-water sites, yielding an estimated capacity of 18 mcy over a period of 6 to 9 years.
- Construct Upper Bay artificial island, yielding an estimated capacity of 50-100 mcy over a period of 13-25 years.

Further details of the plan can be obtained from SOM (1996) and MPA (1996).

1.3.5 Bay Enhancement Phase II Working Group Documents

BEPWG was formed to identify, characterize, and conduct a preliminary screening of potential placement sites to supplement an earlier phase of DNPOP placement site assessments. The Working Group was tasked to identify potential areas that would be suitable for construction of an Upper Bay artificial island site with a beneficial use component. A number of areas were screened by the Working Group based on consideration of capacity, geographic location relative to the channel, bathymetry/hydrography (relative to natural resources and construction), hydrodynamic effects, geotechnical factors, construction materials, beneficial use opportunity, groundwater, sediment quality, water quality, living resources (fisheries, benthos, wildlife, threatened or endangered species), commercial and recreational fishing, cultural resources, marine safety, institutional factors, public and community interests, and costs. However, only limited quantifiable technical information was available to the Working Group to support these deliberations; so, it was not possible to reach a consensus. Therefore, a forced ranking system was employed to arrive at a ranking of the sites. Based on its analysis, the Working Group established the following priority order for locating the Upper Bay island:

- *Priority 1*: Tolchester West & Site 168
- Priority 2: Site 171 (Swan Point West)
- *Priority 3*: Pooles Island Area

Further details of the Working Group ranking process can be obtained from BEPWG (1996).

1.4 Project Scope & Organization

The scope of this project was to conduct a prefeasibility study for Upper Bay long-term placement sites for the Port of Baltimore. In order to conduct the prefeasibility study, the MPA retained four consultants to study the following aspects:

• Earth Engineering & Sciences, Inc. (E2Si)	Geotechnical Investigation
• EA Engineering, Science & Tech., Inc. (EA)	Environmental Investigation
• Gahagan & Bryant Associates, Inc. (GBA)	Dredging & Site Eng. Investigation
• Moffatt & Nichol Engineers (M&N)	Coastal Engineering Investigation

Additional technical support was provided by the Maryland Environmental Service (MES), Maryland Department of the Environment (MDE), and Maryland Geological Survey (MGS). MES also coordinated inter-organization and technical and advisory support for the prefeasibility study at the request of MPA.

The results of the study were to be presented in the following formats: (i) individual technical report by each of the consultants (EA, 1997; E2Si, 1997; GBA, 1997; and M&N, 1997), (ii) a legislative report providing an executive summary of the four reports for the Maryland State Legislature (MPA, 1997), and (iii) a consolidated report summarizing the key aspects of the four reports. This report is a consolidated summary of the key aspects and results of the environmental, geotechnical, dredging and site engineering, and coastal engineering investigations conducted by the four consultants.

1.5 Report Organization

This report is organized as follows: The project objective, project history and description, previous related studies, and project scope and organization are presented in Chapter 1. Details of the site mapping and Geographic Information System (GIS) are presented in Chapter 2. Chapter 3 presents general descriptions of the sites. Chapter 4 presents a summary of the geotechnical investigation conducted by E2Si. The geophysical investigation conducted by MGS is presented as a separate appendix (Appendix B). Chapter 5 presents a summary of the coastal engineering investigation conducted by M&N. Chapter 6 presents a summary of the environmental investigation conducted by EA. Chapter 7 presents a summary of the dredging and site engineering investigation conducted by GBA. The key conclusions of the various investigations are summarized in Chapter 8. A list of references is provided in Chapter 9.

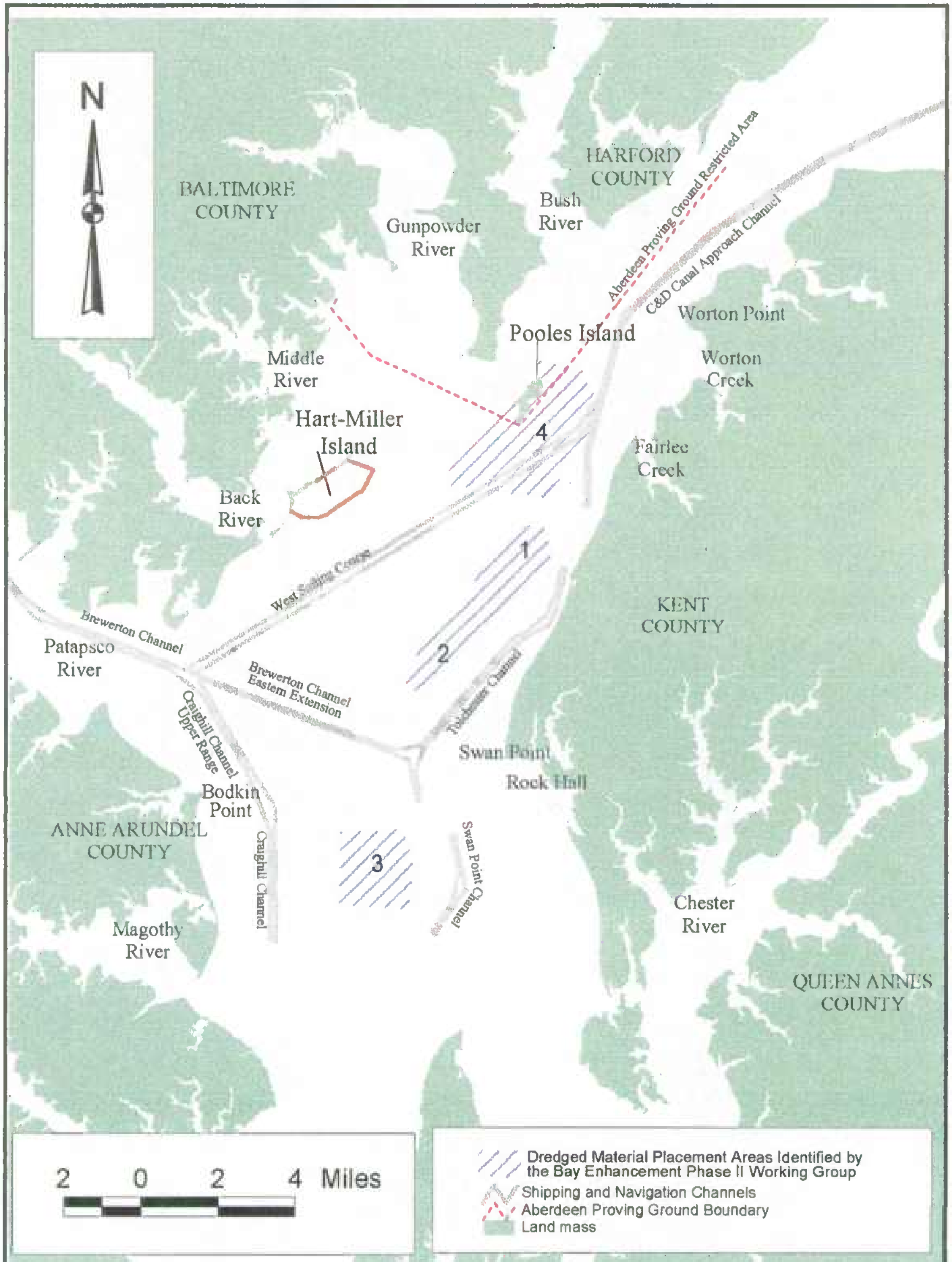


Figure 1-1. Four proposed dredged material placement areas identified through the DNPOP Program.

2.0 SITE MAPPING AND GIS

A comprehensive series of site maps were prepared by GBA and EA with data from MDE and support from E2Si, and M&N, for use by the MPA and other agencies. Information obtained from several sources was digitized to form a series of base maps for the entire study area, as well as for each individual site (see Appendix-A, Plates A-1 through A-9). Maps were updated as new or additional information was available, and updated versions supplied to all members of the design team. The information contained in the maps, and the sources, are briefly described below.

2.1 Existing Site Information

Existing site information included site bathymetry (water depth), existing and/or historical dredged material placement site locations, shipping channels, potential unexploded ordnance (UXO) areas, and site sub-bottom profiles/historic borings. The bathymetric data were obtained from National Oceanic and Atmospheric Administration (NOAA) charts and surveys (NOAA, 1996 and NOAA, 1997) and were incorporated into a base map by GBA. The locations of existing and historic dredged material placement sites as well as the Baltimore Harbor channels were obtained from NOAA charts as well as other sources (MDE, 1997; MES, 1997). The potential UXO areas were assumed to lie predominantly within the boundary of the Aberdeen Proving Ground (APG), and it was acknowledged that there was a high probability of some UXOs lying in the vicinity of the APG boundary. Information on site sub-bottom profiles were obtained from the surveys conducted by the MGS (1997). Information on historic borings (along the old bay bridge alignment) was also obtained from MGS.

2.2 Chesapeake Bay

Information on the Chesapeake Bay included the extent of landward and water boundaries, oyster beds, fishing havens, other environmental data (potential sediment/water column contamination, mapping of benthos, fish, and other sensitive species, and presence and aerial extent of SAV and coastal data (wind directions, wave characteristics, current velocity and direction, and tidal range). Much of this information was made available through the MDE GIS database. Information on land and water areas, as well as oyster beds and fishing havens were obtained from NOAA charts (NOAA, 1996) and the MDE GIS database. Other environmental data and coastal data were obtained by EA and developed by M&N, respectively, and are presented in their reports (EA, 1997; M&N, 1997).

2.3 Four Study Areas

Specific information on the four study areas included geotechnical data (water content, Atterberg limits, specific gravity, grain size distribution, sediment types, consolidation, permeability, and shear strength properties), and site-specific coastal data (wave, current, temperature, conductivity and depth information). The locations of the geotechnical borings and cone penetrometer probings were digitized into the base maps. The geotechnical data were collected by E2Si and are summarized in Chapter 4 and E2Si (1997). GBA provided Quality Assurance/Quality Control, (QA/QC) checks to confirming the accuracy of the boring locations. Geophysical data were provided by MGS based on sub-bottom and side-scan investigations (see Appendix-B). Site-specific coastal data were obtained by the University of Maryland, Horn Point Laboratory, (UMD-HL) under subcontract to MGS. (UMD, 1997)

The general location of and information about existing placement sites and oyster bars are provided as Plates A-1 and A-2 (Appendix-A). Detailed color maps of these features are included in chapters 3 and 7.

3.0 GENERAL SITE DESCRIPTIONS

Site characteristics were determined based on field investigations and/or review of existing data. The following information was gathered:

- *Geophysical Data:* These include site bathymetry (water depth), identification of existing and/or historic dredged material placement sites, identification of potential UXO, and site sub-bottom profiles. The sources of this information can be obtained from section 2.0.

- *Coastal Data:* These include wind directions, wave characteristics, current velocity, and tidal range. Information on wind and wave characteristics as well as tidal range was obtained and developed by M&N (1997) and used to predict wave characteristics for the sites. Selected information on current velocity, as well as conductivity, temperature and depth (CTD) information was obtained using an acoustic doppler current profiler (ADCP) by the UMD-HL, under subcontract to MGS (UMD, 1997). These data were used by M&N to calibrate and verify the hydrodynamic model (M&N, 1997).

- *Environmental Data:* These include a variety of field data (benthic macroinvertebrates, in-situ water quality, and sediment quality/grain size) for each of the five proposed sites. These data also include existing information on fisheries habitat (and fish havens) and oyster bar locations, as well as SAV, wetland and upland habitat distributions at each of the proposed sites. These investigations were conducted by EA (1997).

- *Geotechnical Data:* These include index property tests (water content, Atterberg limits, specific gravity, and grain size distribution); probing/borings, in-situ vane shear tests, cone penetrometer tests (CPT); and consolidation, permeability, and shear strength tests. These investigations were conducted by E2Si (1997) and are summarized in Plates A-7 and A-8.

3.1 Site 1

Site 1 is located north of the Tolchester Channel as shown in Figures 3-1 and 3-2. Water depth at the site varies from approximately 10 ft to 16 ft, with an average value of approximately 12 ft. The greatest fetch direction and hence the largest waves are from the south-southwest direction, while the smallest waves are from the east. There is a fish haven just outside of the eastern portion of the site. Therefore, the site was aligned in such a way as to minimize impacts to this area. There is an unchartered oyster bar near the site. Foundation sediments at the site consists predominantly of silty sands (layer thickness ranging from 10 to 20 ft, with an average value of 15 ft), which approximately follow the 12 ft contour (see Plate No. A-3). This layer is underlain by a 5 to 30 ft silty clay stratum. Details of the coastal, environmental, geotechnical, and dredging and site engineering results are given in M&N (1997), EA (1997), E2Si (1997), and GBA (1997), respectively.

3.2 Site 2

Site 2 is located north of the intersection of Brewerton Channel and Tolchester Channel as shown in Figures 3-1 and 3-3. The site overlaps an existing dredged material placement site along its southern portion. Water depth at the site varies from approximately 16 ft to 28 ft, with an average value of approximately 23 ft. The greatest fetch direction and hence the largest waves are from the south-southwest direction, while the smallest waves are from the east. There are no oyster bars or fishing areas near the site footprint. The southern portion of the site overlays a historical dredged material placement site. Foundation sediments at the site are very weak and consist predominantly of soft to very soft silty clays (layer thickness ranging from 35 to 55 ft). There appears to be a sandy substrate situated outside the current footprint along the northwestern direction. However, additional investigations will be required before the exact location of this alignment can be finalized. Further details of the coastal, environmental, geotechnical, and dredging and site engineering results can be obtained from M&N (1997), EA (1997), E2Si (1997), and GBA (1997), respectively.

3.3 Sites 3 and 3-S

Site 3 (island site) and Site 3-S (submerged confined aquatic site) are located northwest of the Swan Point Channel, as shown in Figures 3-1 and 3-4. These sites are adjacent to two of the largest oyster bars in the northern bay. Water depth at the site varies from approximately 24 ft to 32 ft (with an average value of approximately 28 ft) for Site 3, and from approximately 16 ft to 40 ft (with an average value of approximately 29.5 ft) for Site 3-S. The greatest fetch direction and hence the largest waves are from the south-southwest direction, while the smallest waves are from the east. There are no oyster bars or fishing within along the site footprint. Foundation sediments at the site are very weak and consist predominantly of soft silty clays with layer thickness exceeding 40 ft. Further details of the coastal, environmental, geotechnical, and dredging and site engineering results can be obtained from M&N (1997), EA (1997), E2Si (1997), and GBA (1997), respectively.

3.4 Site 4A

Site 4A is located northeast of Pooles Island, with a small portion lying within the APG boundary line as shown in Figures 3-1 and 3-5. Water depth at the site varies from approximately 10 ft to 34 ft, with an average value of approximately 15 ft. The greatest fetch direction and hence the largest waves are from the south-southwest direction, while the smallest waves are from the east, southeast and northwest. The site overlays a historical dredged material placement site and is located near some productive fishing areas. The site is located approximately 500-1,000 ft off Pooles Island, in order to preserve the shallow water habitat associated with Pooles Island shoreline. If the island is constructed with a breakwater to moderate currents along the Pooles Island shoreline, then the resulting configuration may create a cove that could be beneficial to some species. There is potential for UXO along the entire site, especially along its western boundaries, a situation that will warrant very careful construction procedures. The foundation sediments at the site consist predominantly of gray silty clays (layer thickness exceeding 40 ft). Further details of the coastal, environmental, geotechnical, and dredging and site engineering results can be obtained from M&N (1997), EA (1997), E2Si (1997), and GBA (1997), respectively.

3.5 Site 4B and Site 4B-R

Site 4B is located south of Pooles Island, with some portions lying within the APG boundary, as shown in Figures 3-1 and 3-5. Water depth at the site varies from approximately 4 ft to 16 ft, with an average value of approximately 9 ft. The greatest fetch direction and hence the largest waves are from the south-southwest direction, while the smallest waves are from the east, southeast and northwest. The site is located near some productive fishing areas, which may be affected during construction. Also, UXO are likely to be present throughout the site as this area was previously a target for gunnery practice and tests outside of the APG boundary. To protect the shallow water habitat, bald eagle nests, and historic/archeological resources, a sub-site (Site 4B-R) was also laid out for consideration as shown in Plate No. A-6. Foundation sediments here are highly variable, ranging from predominantly gray silty sands with gravel (average layer thickness greater than 5 ft) underlying a layer of gray silty clay at the north end of 4B, to predominantly dark gray to black silty clays (layer thickness exceeding 30 ft) at 4B-R. Further details of the coastal, environmental, geotechnical, and dredging and site engineering results can be obtained from M&N (1997), EA (1997), E2Si (1997), and GBA (1997), respectively.

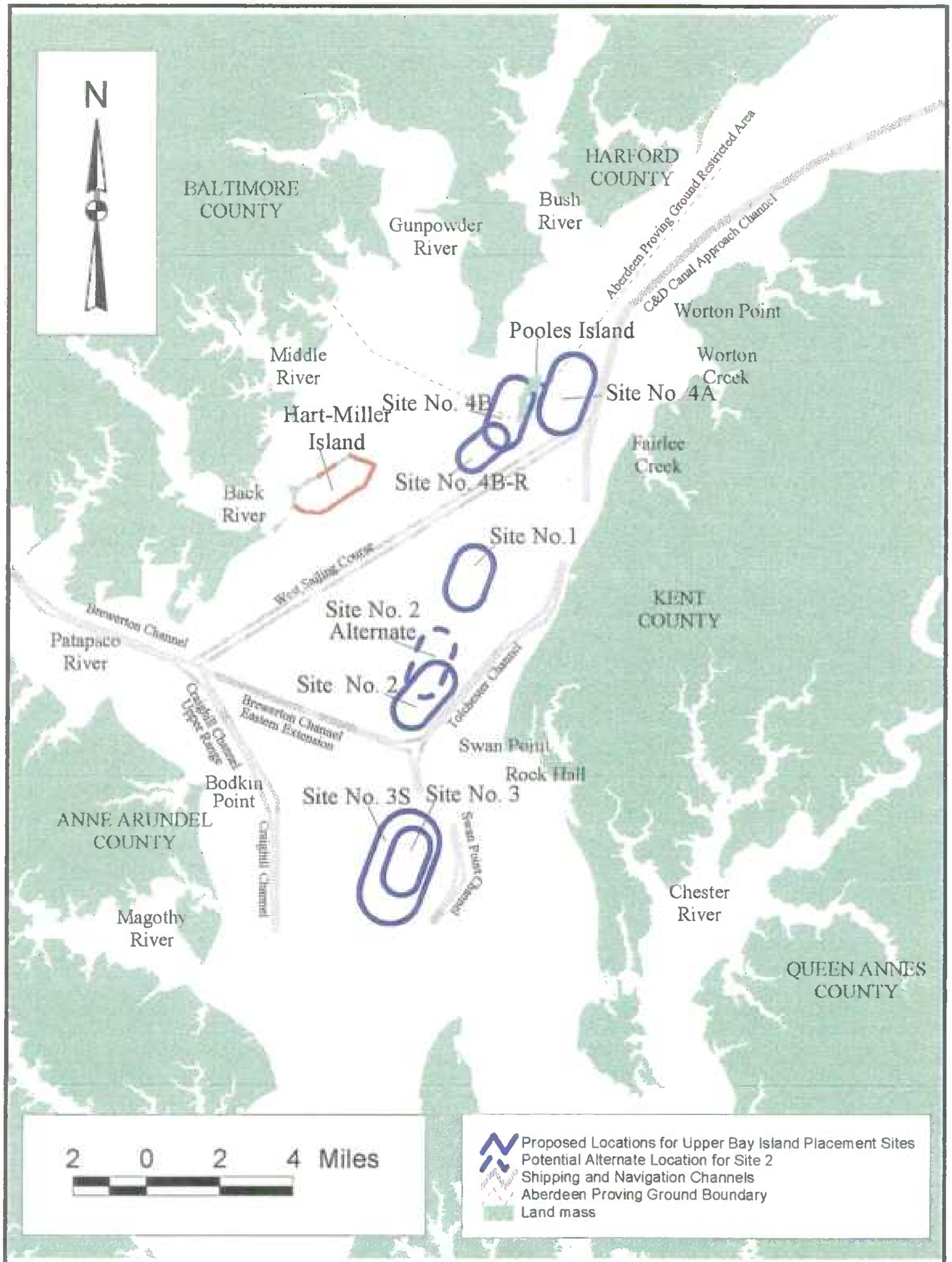


Figure 3-1. Proposed locations for Upper Bay Island placement sites.
All sites sized to reflect 80 mcy capacity. Environmental investigation considered 2,000 acres from centerpoint of sites depicted here.

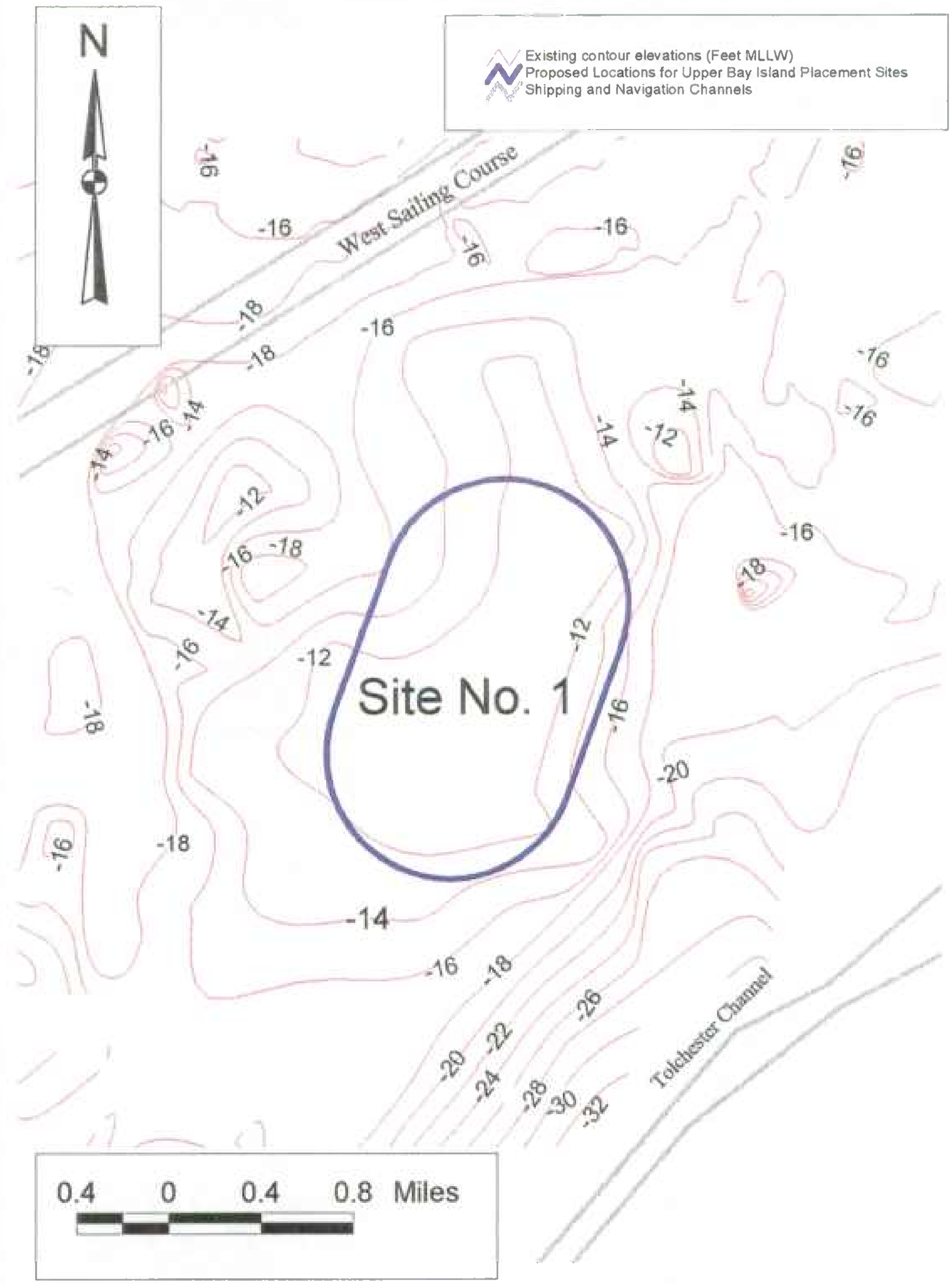


Figure 3-2. Proposed Site No. 1 and existing bathymetry contours.

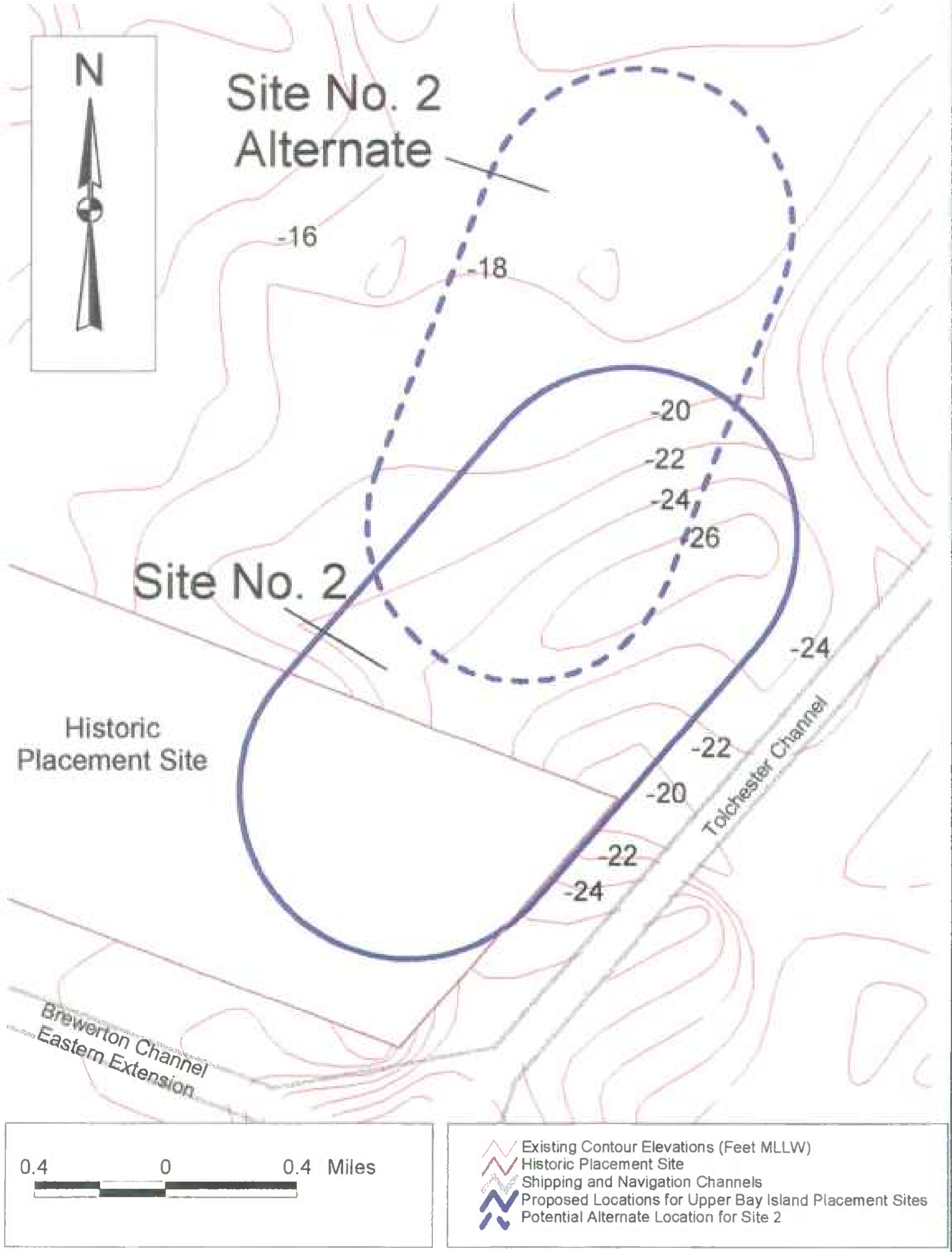


Figure 3-3. Proposed Site No. 2 and existing bathymetry contours.

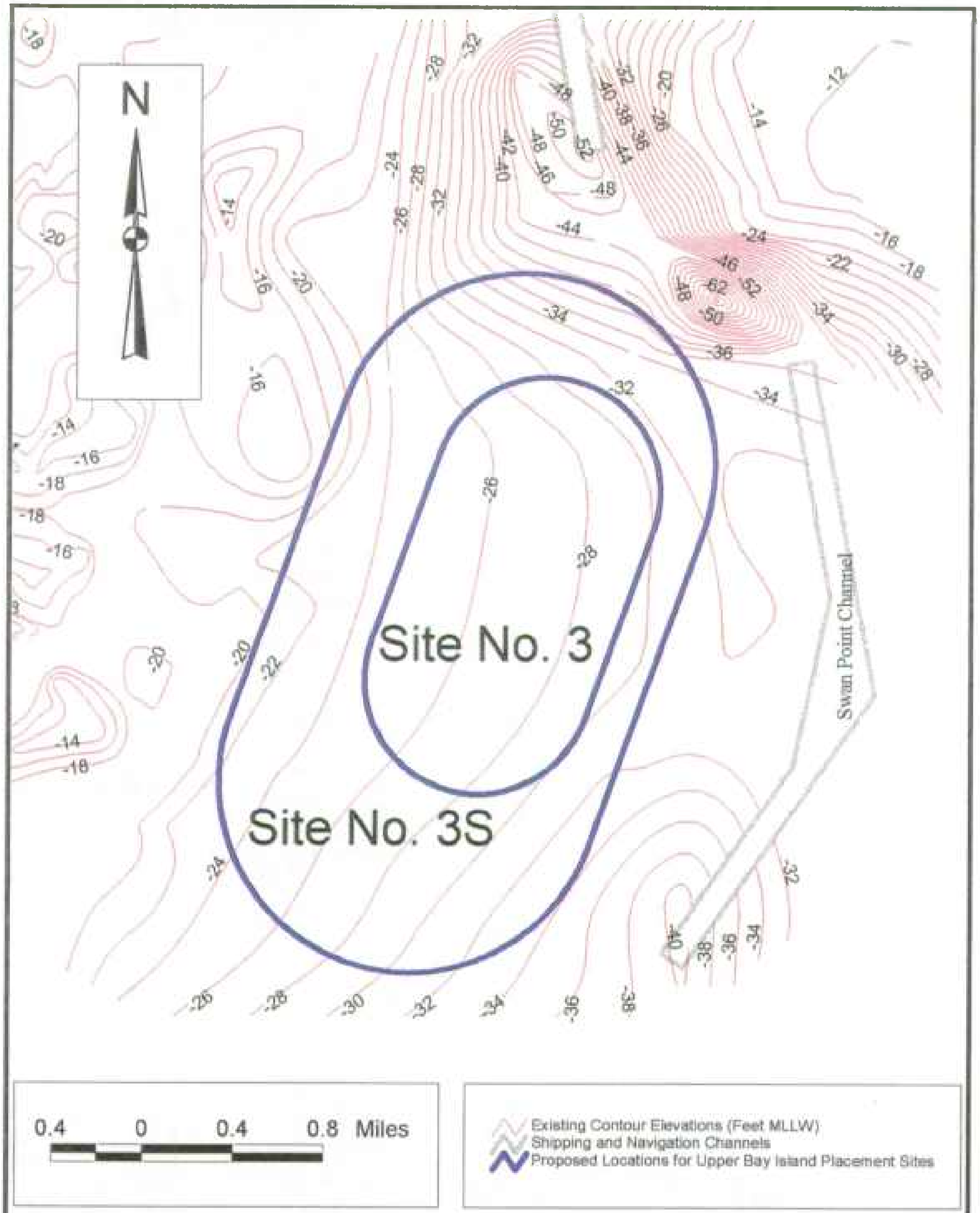


Figure 3-4. Proposed Site No. 3 and No. 3S and existing bathymetry contours.

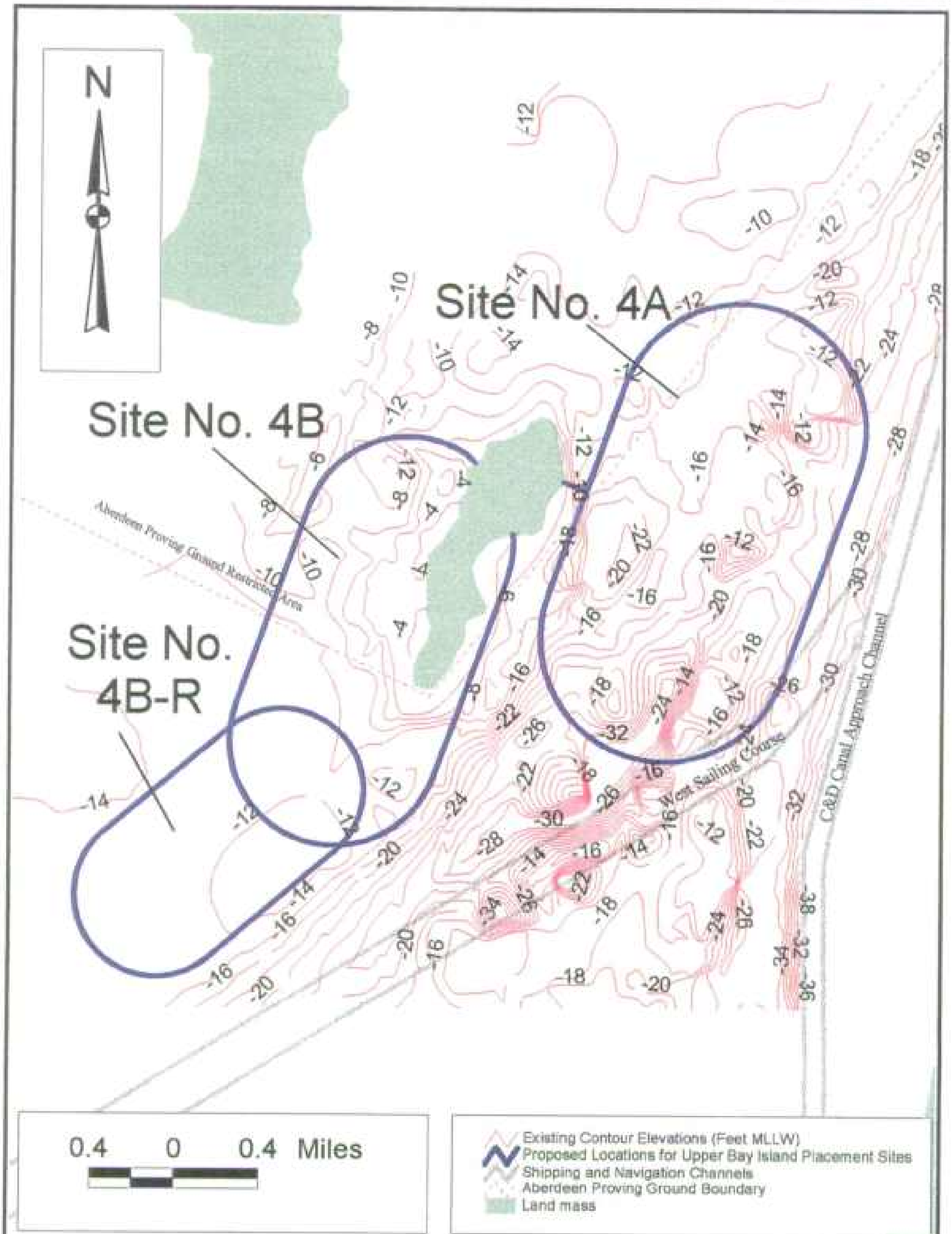


Figure 3-5. Proposed Site Nos. 4A, 4B, and 4B-R and existing bathymetry contours.

4.0 GEOTECHNICAL INVESTIGATION

4.1 Field Investigation

The field investigation was conducted in July 1997 at Areas 1, 2, and 3, and in September 1997 at Areas 4A and 4B.

For Areas 1, 2, and 3, a CME 75 truck rig was modified to accommodate the CPT equipment and was mounted on a 60 ft. x 90 ft. steel barge. Work was conducted 24 hours/day, 5 days/week, weather permitting. Borings were located in the field using a NORTHSTAR Global Positioning System (GPS) with a differential. The accuracy of the first location was independently checked by Gahagan & Bryant Associates (GBA). The boring location was within about 20 ft, as determined by E2Si and by GBA. All other borings were located by E2Si using the NORTHSTAR system. The boreholes were advanced using hollow stem augers. Water depths were measured at each boring location, using a weighted tape. The locations of the borings are shown graphically on Figure 4-1 through Figure 4-4 and are tabulated on Table 4-1. The locations of the borings and the MGS acoustic profiles are shown on Figure 4-5.

At Areas 4A and 4B, the steel barge could not be used. These areas are known to have UXO. Therefore, the locations of the borings had to be checked for the presence of UXO. This could not be done using a steel barge, as the steel interferes with the UXO identification process. Consequently, the borings were drilled using a tripod, mounted on a styrofoam barge. A health and safety plan for drilling the borings was prepared. Each boring location was checked for the presence of UXO. The bore holes at Area 4A and Area 4B were advanced using the wash and drive method and a 3 inch casing. At each of the five areas, standard penetration tests were conducted and split spoon samples were obtained in every boring at depth intervals of 2.5 ft. A representative portion of each sample was placed in a glass jar, and was appropriately marked. Shelby tube samples were attempted in cohesive soils by pushing the tubes. In most instances, shelby tube samples could not be obtained since the soil was too soft. Only 5 shelby tube samples were recovered, out of a total of 17 attempts. In-situ vane shear tests were conducted by pushing a 6 inch long vane, with a diameter of 2.5 inches. Torque was applied and measured using the Acker System. The results of the vane shear tests are shown on Table 4-2. The depths of the borings varied from about 40 ft to about 77.5 ft. The edited logs of the borings are included in the Appendix.

Electric CPT were conducted at each of the three Areas (1, 2 and 3) at locations shown on Figure 4-1, Figure 4-2 and Figure 4-3. The electronic CPT were conducted in accordance with ASTM D-3441 by pushing (not driving) a 1.55 square inch cone and 1.4 inch diameter rods. The tip resistance, the local sleeve friction and the pore pressures were recorded electronically at depth intervals of 5 centimeters, as the rod/cone assembly was pushed. The data recorded in the field is included in the Appendix. The depth of the CPT holes varies from 10 ft to 55 ft.

4.2 Laboratory Testing

All samples were visually classified in the laboratory by a geotechnical engineer to corroborate and/or modify the field classifications. Selected samples were tested for their natural water content, Atterberg Limits, sieve analyses, unconfined compressive strengths and consolidation characteristics. A total of 308 water contents, 46 Atterberg limits, 30 sieve analysis, 5 unconfined compression strength and 5 consolidation tests were conducted. All tests were conducted in accordance with ASTM procedures. The results of the laboratory tests are included in the Appendix in tabular and/or graphical form.

4.3 Area Geology

Geologically, the site lies in the Coastal Plain Physiographic Province. The soils in the area are of marine and/or fluvial origin. The depth to rock is several hundred feet. The surficial soil formation at the site is the Lowland Deposits, which consists of gravel, sand, silt and clay. It is generally underlain by the Potomac Group. However, the upper part of the Lowland Deposits/Potomac Group was eroded and the eroded channels/areas were filled with marine clay.

4.4 Subsurface Conditions

The subsurface conditions at each of the five areas are discussed separately. The generalized subsurface profiles for each area are shown on Figure 4-6 through Figure 4-15.

4.4.1 Area 1

The subsurface conditions here vary significantly as shown on Figure 4-6, Figure 4-7 and Figure 4-8 and generally consist of the following major strata:

Stratum 1: This consists of very loose to very dense gray and brown silty sand. Standard penetration resistance varies from about 6 to 48 blows/foot. Fines content (i.e. percent passing U.S. standard sieve No. 200) is generally between 10% to 15%. This stratum occurs at the mud line (about El. -15 to El. -20), within approximately contour El. -12, and is about 10 to 20 ft thick. The sand is semi-angular to angular, and is generally medium to fine.

Stratum 2: This underlies Stratum 1, and consists of soft to stiff, gray silty clay. Its thickness varies from about 5 to over 30 ft. Standard penetration resistance varies from 2 to about 20 blows/foot, and is between 12 to 15 blows/foot. Its liquid limit (LL) is about 45, plasticity index is about 17, and the water content is between 33% to 40%. Torvane tests indicate that the cohesion is about 500 psf to 800 psf. Consolidation tests conducted on two samples from boring B-1-1 and boring B-1-5 at about El.-45 and El.-53 respectively, indicate that the silty clay is normally consolidated to slightly preconsolidated, with the Over Consolidation Ratio (OCR) being about 1 to 2.

Stratum 3: This consists of very soft, dark gray silty clay, with a standard penetration resistance of weight of rods (WOR). It generally occurs outside the El. -12 contour, and was encountered in C1-1, C1-3, C1-4 and SB1-1. It extends from the mud line (about El. -15 to El. -20) to about El. -40. The CPT indicate that shear strength is less than 100 psf. Laboratory tests indicate that the natural water content is generally between 90% to 130%, LL is above 80, the plasticity index is about 50, and the organic content is about 6%.

Stratum 4: This stratum underlies the entire area and consists of medium dense to dense brown and gray silty sand with gravel. The top of this stratum varies considerably from about El. -35 (Boring SB1-1) to below El. -55.

4.4.2 Area 2

The subsurface conditions here generally consist of three major strata, as shown on Figure 4-9 and Figure 4-10. The strata are:

Stratum 1: This consists of dark gray to black, silty clay. It extends from the mud line (about El. -20 to El. -30) to about El. -30 to El. -40. Standard penetration resistance was generally WOR. The natural water content varies from about 120% to 140%; LL varies from 84 to 110; plasticity index varies from 52 to 75; and organic content is about 8% to 12%. CPT indicate that the shear strength is less than 100 psf. Shelby tubes could not be obtained in this stratum, due to the very soft nature of the clay. Torvane tests could not be conducted on split spoon samples because the samples slumped under their own weight.

Stratum 2: This stratum underlies Stratum 1, and consists of very soft to soft gray silty clay. Standard penetration resistance was generally WOR. It extends from about El. -35 to about El. -50 to El. -70. The natural water content is generally between 100% to 120%, LL is between 85 to 110, plasticity index is between 45 to 75. The water content generally reduces with depth, and is generally above the LL. The organic content is about 7%. CPT indicate that the shear strength increases with depth and varies from about 250 psf near the top of the stratum to about 700 psf near the bottom of the stratum. This linear increase of strength with depth is indicative of the clay being normally consolidated.

Stratum 3: It underlies Stratum 2, and generally consists of medium dense to very dense brown silty sand with gravel. The top of the stratum varies from about El. -45 to about El. -70. Standard penetration resistance varies from 20 blows/foot to over 50 blows/foot.

4.4.3 Area 3

The subsurface conditions here generally consist of two major strata, as shown on Figure 4-11, Figure 4-12 and Figure 4-13.

Stratum 1: This consists of dark gray and black silty clay, and extends from the mud line (El. -25 to El. -30) to about El. -35 to El. -40. Standard penetration resistance is WOR. Natural water content is generally in excess of 130%; LL is greater than 110; plasticity index is in excess of 70. Based on CPT, the shear strength is less than 100 psf.

Stratum 2: This consists of gray silt clay, and extends to below El. -80. Natural water content varies from about 90% to 130%; LL is between 95 to 110; plasticity index is between 58 to 65. CPT indicate that the shear strength increases with depth, and varies from about 250 psf near the surface to about 800 psf at about El. -80. Consolidation test conducted on one sample (B3-3, El. -79) indicates that the stratum is normally consolidated.

4.4.4 Area 4A

The subsurface conditions here generally consist of one major stratum, as shown on Figure 4-14. The stratum is:

Stratum 1: This consists of gray silty clay. It extends from the mudline (about El. -20) to the bottom of the boring (about El. -45). Standard penetration is WOR. Natural water content decreases with depth and varies from about 90% to about 115%. The LL is generally between 65 and 70, and the plasticity index is between 25 and 40. This stratum is believed to be normally consolidated, based on correlation with similar soils at Area 2 and Area 3. The shear strength increases with depth and is estimated to be less than 100 psf in the top 10 ft and about 250 psf below a depth of 10 ft.

4.4.5 Area 4B

The subsurface conditions here vary considerably from north end to south end, as shown on Figure 4-15, and generally consist of the following strata:

Stratum 1: This consists of dark gray to black silty clay, and was encountered in boring 4B-2 only. It extends from the mud line (El. -13) to about El. -18.

Stratum 2: This consists of gray silty clay. The standard penetration resistance is WOR. Its thickness varies considerably from about 8 ft in boring 4B-1 to over 15 ft in boring 4B-2. Its natural water content varies from about 120% to about 150%, and generally decreases with depth. Its LL is about 70, and plasticity index is about 38. The shear strength is estimated to be about 250 psf, and is anticipated to increase linearly with depth.

Stratum 3: This consists of gray silty sand with gravel, and was encountered below Stratum 2 in boring 4B-1 only. Standard penetration resistance is about 50 blows/foot. The thickness of the stratum is not known, since the boring (which was drilled using a tripod) could not be advanced below El. -20 (depth of about 10 ft below mudline).

4.5 Geotechnical Findings

From geotechnical considerations, five areas (Site 1, Site 2, Site 3, Site 4A and Site 4B) were evaluated. Different sites within a given area (except Site 4B) were not treated differently, since the borings covered the general area, and not a specific site within that area. In Site 4B, two separate sites (Site 4B-1 and Site 4B-R) were evaluated, since the subsurface conditions are anticipated to be significantly different at each of these two sites.

4.5.1 General

The two major issues concerning the evaluation of a dredged material placement site are:

a) *Borrow:* Availability of suitable borrow material within the contained area. The borrow should ideally be a sand, with as little fines (i.e. percent passing U.S. Standard sieve #200) as possible. If sand is not available locally, it will either have to be imported (which increases the cost significantly), or the dike would have to be constructed from on-site clay (usually not practical due to the low strength of clay placed in the dike), or another type of containment structure would need to be used.

b) *Foundation*: Foundation conditions under the containment (perimeter) dike. Soft clays would require flatter slopes for the dike, or steeper slopes and stabilizing berms. Stiff clays and sands are the preferred conditions. Flatter slopes or berms would increase the cost. Additionally, areas that have very soft clays may require the total or partial removal (either by displacement or by undercutting) of the very soft clay. The undercut soil has to be disposed of, either on-site or off-site, and the undercut area has to be backfilled with sand.

In evaluating the stability of a slope, three variables have to be considered:

i) Shear strength of the foundation soil
ii) The slope of the dike
iii) The acceptable factor of safety.

At each site, the shear strength was based on the combined evaluation of SPT, CPT, vane shear and laboratory data. Since the SPT value in the clay was generally WOR or weight of hammer (WOH), the SPT was given the least credence. No numerical value of shear strength could be obtained from SPT. Stress history of each area was evaluated, based on consolidation tests, to determine whether the clays are normally consolidated or overconsolidated. This was further evaluated based on the CPT data. A linear increase of strength with depth was considered to be indicative of normally consolidated soil. Well accepted and established empirical relationship between PI and $Su/\sigma_{c'}$ was used to establish the probable limits of the in-situ strengths. The field and laboratory strength data that fell outside these probable limits was given less weight or was ignored.

During construction, the slope of the dike can vary considerably. Past experience has shown that dikes can be constructed from hydraulically dredged and placed sands.

Slopes of about 3H:1V can be achieved under water, and, with proper construction techniques, slopes above water can also be 3H:1V. These slopes have been used at HMIs DMDF and at Poplar Island Restoration Project. Therefore, the slopes of the dikes were assumed to be 3H:1V.

The acceptable factor of safety was assumed to be 1.3, at the end of dike construction phase. This was also based on the experience at HMI and Poplar Island Project, and was considered to be acceptable to the USACE. USACE will be involved in the permit process, and will review and approve the final design.

4.5.2 Relative Area Evaluation Methodology

It was recognized that from geotechnical considerations each area could be developed. The geotechnical considerations could, however, have a major impact on the cost, since they would determine the dike cross section, the amount of undercutting of poor soils in the foundation, and the availability of borrow material in the area for the construction of the dike. Therefore, the relative area evaluation was based on the following:

Parameter	Condition	Rating
Foundation (Dike Cross-Section and undercutting)	• Small volume/L.F. of dike	Most desirable
	• Large volume/L.F. of dike	Least desirable
Borrow	• Sand and gravel on site >15 ft. thick minimal cover	Most desirable
	• Sands on site <15 ft. thick minimal cover	Desirable
	• Silty sands on site >15 ft. thick, some cover	Somewhat desirable
	• Discontinuous layers of sand on site	Least desirable
	• No sand on site	Not desirable

Since the area of the proposed facility was flexible, and could be varied from 500± acres to 2000± acres, and the capacity of the site was fixed, the dike height did not have to be very high. It was decided to obtain a dike cross section that would have a factor of safety of 1.3 with the top of dike being at El. +15. The relative evaluation of the areas from foundation considerations was based on this cross-section.

4.5.3 Settlement Analysis

Settlement analyses, while of significance in the final design are not significant at this relative site evaluation phase. Magnitude of settlement will affect the capacity of the site by a minimal amount (<5%). This additional volume can be obtained easily in the final design phase by realigning the dike.

Nevertheless, preliminary settlement analysis, based on very limited data, were conducted, and the results are summarized below:

Site	Estimated Settlement		
1	6 inches	to	12 inches
2	1 ft	to	2 ft
3	1 ft	to	2 ft
4A	1 ft	to	2 ft
4B	6 inches	to	2 ft

It should be noted that the above settlements are the settlements under the dike only, and not in or under the dredged material placed in the confined area. It was recognized that the settlement profile would be saucer shaped, with the settlement being maximum under the center of the dike and being least at the edge. At this pre-feasibility study phase, such details were not considered. The approximate settlement reported is that under the center of the dike.

4.5.4 Slope Stability Analysis

Slope stability analyses were conducted for each area, using one typical case for subsurface profile. Purdue University PC STABL V program was used to analyze the stability of the slopes. Both circular and wedge (block) failures, were investigated. Slopes as flat as 10H:1V were investigated to achieve the acceptable factor of safety of 1.3. It was recognized that using stabilizing berms, rather than very flat slopes, would be more economical. Therefore, the final dike slopes were maintained at 3H:1V wherever possible, and the length of the berm was varied to obtain a factor of safety of 1.3, and a dike height of at least El. +15.

After the first several trials, it became apparent that the critical failure (i.e. the one with the least factor of safety) was the wedge failure, and not the circular failure. Therefore, all further analyses were limited to the wedge failure.

4.5.5 Increase of Shear Strength With Time

It was recognized that the shear strength of the foundation clay will increase with time, as the clay consolidates under the weight of the berm and the dike. The final increase in strength would be a function of the weight of the berm and the elapsed time. Since the clay stratum at each of the Sites (i.e. Site 2, Site 3 and Site 4A), is quite similar, separate analyses for increase in shear strength were not conducted for each Site. For an additional stress from the dike and berm of about 1000 psf, the ultimate increase in strength would be about 350 psf. It was assumed that the increase in strength in about 5 to 10 years would be about one third of the ultimate increase, or about 100 psf. Additional slope stability analyses were conducted for each Site with clay foundations, to estimate the additional height to which the dike could be raised, based on an increase in shear strength of about 100 psf.

4.5.6 Site 1

a) *Foundation Conditions*: It was assumed that about 3 ft of soil would either be displaced or would need to be undercut. Based on this, various slopes and dike heights were analyzed. For pre-feasibility and relative site evaluation purposes, the dike section shown on Figure 4-16 with top of dike at El. +25 should be used.

b) *Borrow*: The borings indicate that up to 15 ft of slightly silty to silty sand with gravel, with minimal cover, is available at the Site. The thickness of cover is minimal, therefore, the site was assigned a score of 2 from borrow considerations.

4.5.7 Site 2

a) *Foundation Conditions*: The foundation soils under the dike are anticipated to be soft to very soft silty clay, to about El. -50 (See Figure 4-9).

The borings indicate that the standard penetration resistance in the upper 30 ft is WOR or WOH. The CPT data indicates that the shear strength increases linearly with depth, hence the clay is normally consolidated. This is corroborated by the consolidation tests, which indicate that the pre-consolidation pressure (P_c') is about 0.6 TSF. The following strength parameters were used in evaluating the stability of the slopes:

Elevation	Cohesion (psf)	ϕ (Degrees)
-25 to -35	0	0
-35 to -50	300	0
-50 to -60	500	0

Slope stability analyses were conducted for different slope configurations. It became apparent that the soft foundation soils could not support a conventional dike with slopes of 3H:1V or even 8H:1V. Therefore, it was assumed that the very soft soils would be undercut to about El. -35 and a stabilizing berm was included in the analyses. The recommended dike section for dike at El. +10 is shown on Figure 4-17.

Stability analyses were also conducted for dikes at El. +12 and El. +15.

It was assumed that the shear strength of the clay would increase with time. Analyses were conducted to evaluate the height to which the dike could be increased after 10 to 15 years, while still achieving a factor of safety of 1.3. The analyses indicate that the dike can be raised to El. +19.

b) *Borrow Site*: The data indicate that there is no sand or gravel available at the site to build the dike. The clay is very soft, and is not considered to be suitable for building the dike, even if it were to be excavated by a dragline rather than by hydraulic dredging. Therefore, either the sand for building the dike will have to be imported, or the containment structure will have to be something other than a dike. The site was ranked "Not desirable" from borrow considerations.

There is a possibility that sand may be available from the site north-west of the site. It is recommended that the area north and west of the site be further investigated for the presence of sand.

4.5.8 Site 3

a) *Foundation Conditions*: The foundation soils under the dike are anticipated to be soft to very soft silty clay, to about El. -55.

The borings indicate that the standard penetration resistance in the upper 30 ft to 40 ft of soil is WOR or WOH. The CPT data indicates that the shear strength increases linearly with depth. Hence the clay is normally consolidated. This is corroborated by the consolidation tests, which indicate that the pre-consolidation pressure (P_c') is about 0.7 TSF. The following strength parameters were used in evaluating the stability of the slope:

Elevation	Cohesion (psf)	ϕ (Degrees)
-25 to -40	0	0
-40 to -55	250	0
-55 to -70	450	0

Slope stability analyses were conducted for different slope configurations. It became apparent that the soft foundation soils could not support a conventional dike with slopes of 3H:1V or even 8H:1V. Therefore, it was assumed that the very soft clay would be undercut to El. -40, and a stabilizing berm was included in the analysis. The recommended dike section for dike at El. +8 is shown on Figure 4-18.

Stability analyses were also conducted for dikes at El. +12 and El. +15.

It was assumed that the shear strength of the clay would increase with time. Analyses were conducted to evaluate the height to which the dike could be increased after 10 to 15 years, while still achieving a factor of safety of 1.3. The analyses indicate that the dike can be raised only to El. +16.

b) *Borrow Site*: The data indicate that there is no sand or gravel available at the site to build the dike. The clay is very soft, and is not considered to be suitable for building the dike, even if it were to be excavated by a dragline rather than by hydraulic dredging. Therefore, either the sand for building the dike will have to be imported, or the containment structure will have to be something other than a dike. The site was ranked "Not desirable" from borrow considerations.

4.5.9 Site 4A

a) *Foundation Condition*: The foundation soils under the dike are anticipated to be soft to very soft silty clay to at least El. -45. The soft clay could, and probably does, extend to a much deeper depth.

The borings indicate that the standard penetration resistance is WOR. No laboratory or field data are available to quantify the shear strength or the stress history. However, based on the water contents and the similarities with Site 2 and Site 3, it is believed that the clay is normally consolidated. The shear strength in the upper 10 ft to 15 ft is anticipated to be less than 100 psf. Below that depth, the shear strength is anticipated to be about 250 psf. For pre-feasibility analysis, the following strength parameters were used in evaluating the stability of the slope:

Elevation	Cohesion (psf)	ϕ (Degrees)
-20 to -30	<100	0
-30 to -50	250	0
Below -50	500	0

Slope stability analyses were conducted for different slope configurations. It became apparent that the soft foundation soils could not support a conventional dike with slopes of 3H:1V or even 8H:1V. Therefore, it was assumed that the very soft clay would be undercut to about El. -30 and a stabilizing berm was included in the analysis. The recommended dike section for dike at El. +8 is shown on Figure 4-19.

Stability analyses were conducted for dikes at El. +12 and El. +15.

It was assumed that the shear strength of the clay would increase with time. The analyses for evaluating the height to which the dike can be raised while still achieving a Factor of Safety of 1.3, are identical to that for Site 3. Therefore, the dike can be raised to about El. +16.

b) *Borrow Site*: The data indicate that there is no sand or gravel available at the site to build the dike. The clay is very soft, and is not considered to be suitable for building the dike, even if it were to be excavated by a dragline rather than by hydraulic dredging. Therefore, either the sand for building the dike will have to be imported or the containment structure will have to be something other than a dike. The site was ranked "Not desirable" from borrow considerations.

4.5.10 Site 4B-1 and Site 4B-2

a) *Foundation Conditions*: No borings were drilled in the vicinity of the northern portion of Site 4B-1 or 4B-2. It was assumed that the subsurface conditions here are represented by boring 4B-1 i.e. about 8 ft of soft clay underlain by dense sand. It was assumed that the soft clay would be undercut to the top of the sand, and the dike would bear on the sand directly. Slope stability analysis were conducted based on this assumption. The recommended dike section is shown in Figure 4-20. It consists of a 3H:1V slope bearing on the sand stratum, regardless of the elevation of the top of dike.

b) *Borrow Site*: The data indicates that the sand is likely to be available at the site. Recovering the sand will require some stripping. The thickness of the sand is unknown. It is conceivable that depending upon the quantity of sand required, some sand may have to be imported.

It should be noted that this site is known to have UXO. Technology for mining sand in the presence of UXO may not be readily available. Therefore, because of the presence of UXO, it may not be feasible to use the local sand for borrow.

4.5.11 Site 4B-R

a) *Foundation Conditions*: The foundation soils under the dike are anticipated to vary from north end to south end. Near the south perimeter, the soils are anticipated to be very soft to soft silty clay to at least El. -35 (i.e. 20 ft below the mud line, which is at El. -10 to El. -13). The soft clay could, and probably does, extend to a deeper depth. Near the north perimeter (i.e. closer to Pooles Island), the soils are anticipated to be soft clay (of variable thickness), underlain by dense sand. Consequently, the dike sections at Site 4B-R could vary from a dike with no stabilizing berms to a dike with stabilizing berms. The locations where the dike sections may change from dike with no berm to dike with berm, are not known at this stage. Since the vast alignment of the dike at Site 4B-R will be south of boring 4B-1 (and in area of soft clay), it was assumed that the entire dike will lie over the soft clay conditions represented by boring 4B-2. No quantitative data is available regarding the shear strength of the soft clay. Since the clay is similar to that at Site 2 and Site 3, it was assumed that the shear strength is less than 100 psf in the top 8 ft (down to El. -20); is about 250 psf below that (down to El. -50); and increases with depth.

For pre-feasibility analysis, the following strength parameters were used:

Elevation	Cohesion (psf)	ϕ (Degrees)
-12 to -20	<100	0
-20 to -50	250	0
Below -50	800	0

It should be noted that the above conditions represent those anticipated at the south end.

Slope stability analyses were conducted for different slope configurations. It became apparent that the soft foundation soils could not support a conventional dike with slopes of 3H:1V or even 8H:1V. Therefore, it was assumed that the very soft clay would be undercut to about El. -20 and a stabilizing berm was included in the analysis. The recommended dike section for dike at El. +8 is shown on Figure 4-21.

Stability analyses were also conducted for dikes at El. +12 and El. +15.

It was assumed that the shear strength of the clay would increase with time. The analyses for evaluating the height to which the dike can be raised while still achieving a Factor of Safety of 1.3, are identical to that for Site 3. Therefore, the dike can be raised to about El. +16.

b) *Borrow Site*: The data indicate that sand is likely to be available in the northern portion of the site, close to Pooles Island. Recovering the sand will require some stripping. The thickness of the sand is unknown. It is conceivable that depending upon the quantity of sand required, the sand may have to be imported. For budgeting purposes, it should be assumed that about 50% of the sand may need to be imported. It should be noted that this area is known to have UXO. Technology for mining sand in the presence of UXO may not be readily available. Therefore, because of the presence of UXO, it may not be possible to use the sand for borrow.

4.5.12 Subaqueous Site - Site 3-S

Site 3 has relatively deep water, with the depth of the water being about 25 ft to 30 ft. Therefore, this site could conceivably be developed as a subaqueous site, where the top of the containment dike would be at about El. -10. Slope stability analyses conducted for the stabilizing berm at Site 3 (with the top of the berm being at El. -10) are also applicable to the subaqueous site, Site 3-S (i.e. the stabilizing berm will become the subaqueous dike). Based on those analyses, it is apparent that a subaqueous dike can be constructed to El. -10, with a slope of 5H:1V and a factor of safety in excess of 1.3. The sand for the dike will have to be imported.

4.5.13 Summary of Slope Stability Analysis

A total of 19 different cases (for all sites) were analyzed. The assumptions and the results of the analysis are summarized on Table 4-3.

4.5.14 Volume Analysis

Since one of the variables in the relative site evaluation is the volume required/L.F. of dike, the volume of the dike for the recommended dike section was computed for each case. The data is summarized on Table 4-4.

For a given dike height, Site 1 required the least volume/L.F. and Site 3 required the most volume/L.F.

4.5.15 Displacement / Undercutting of Soft Clays

Very soft clays are anticipated almost under the entire length of the dike at Site 2, Site 3, and Site 4A. Site 4B is anticipated to have about 5 ft of very soft clay in the northern portion and about 10 ft in the southern portion. At Site 1, some localized sites of very soft clay should be anticipated under the dike. These very soft soils can either be undercut , or they can be displaced by the dike. In either case, they will have to be removed from the dike template site. The soil displaced to the front of the construction face of the dike, and to the face that will receive the slope protection, can not be left in the displaced position, and will have to be removed. The soil displaced to the side that will not receive any slope protection (inside slope), can be left in the displaced position. When preparing the cost estimates, the impact of the displacement/undercutting should be considered. It has been assumed that displacement/undercutting will be minimal at Site 1. At Site 2, the depth of displacement/undercutting will be about 10 ft; and that at Site 3 will be about 15 ft; that at Site 4A will be about 10 ft and that at Site 4B will average about 8 ft.

It may be possible to reduce the volume of undercut (not the depth), by employing such concepts as displacement (no undercutting) under the interior slope. Use of such approaches to reduce cost can be evaluated in the feasibility study phase and in the design phase.

4.5.16 Alternative Approach

The conventional approach discussed above for Sites 2 and 3 consists of installing a stabilizing berm and constructing the dike on it.

An alternative to the above approach would be to delete the berm, install the dike in stages, and install wick drains. The wick drains will speed up the consolidation process, and hence speed up the gain in strength. The dike would act as the surcharge.

Based on this concept, we envision the following steps:

i) Excavate the very soft soil to about El. -35 or El. -40.

ii) Construct the dike to El. -10, using the same template as that for dike to be built to El. +15.

iii) Install wick drains from El. -10 to El. -50, at about 4 ft to 5 ft on center.

iv) Wait about one to two years. The shear strength will increase from the current 300 psf to about 400 psf.

v) Raise the dike to El. 0. Wait about one to two years. The shear strength will increase from about 400 psf to about 500 psf.

vi) Raise the dike to El. +10, wait about one to two years. The shear strength will increase to about 600 psf.

vii) Raise the dike to El. +15.

This approach offers several advantages:

i) Reduces the volume of sand needed, since the stabilizing berm will not be required.

ii) Reduces the volume of the unsuitable soft clay to be undercut from the dike foundation. Since the undercut material will be placed in the site confined by the dikes, the capacity of the confined site will be reduced by a smaller volume.

iii) The dike can be constructed in stages, thus reducing the initial cost.

The disadvantages of this approach are:

i) The outside slope will have to be protected, just as for the conventional dike. However, the slope protection will have to be added every time the dike is raised. This will increase the cost of slope protection.

ii) The top of the dike, when below El. 15, will be subject to overtopping. Consequently, the top of the dike may need to be protected from erosion and wave action, which will add to the cost.

4.5.17 Relative Site Evaluation

Based on the investigation conducted, it is concluded that the proposed dikes can be constructed at any of the sites. The relative area evaluation, from geotechnical considerations, is as follows:

Site	Criteria	Relative Evaluation
Site 1	Foundation	Most desirable (Within contour El. -12)
	Borrow	Desirable
Site 2	Foundation	Least desirable
	Borrow	Not desirable
Site 3	Foundation	Least desirable
	Borrow	Not desirable

Site	Criteria	Relative Evaluation
Site 4A	Foundation	Least desirable
	Borrow	Not desirable
Site 4B-1	Foundation	Desirable
	Borrow	Somewhat desirable*
Site 4B-R	Foundation	Least desirable
	Borrow	Not desirable*

NOTE:* Excludes effect of UXO.

4.5.18 Limitations

It should be clearly understood that this is not intended to be a design section. The basic purposes of this study were to obtain preliminary information about the subsurface conditions at each of the five sites, and to evaluate their impact on the preliminary cost estimates for comparative or relative site evaluation purposes. The recommended dike design sections and depth of undercut are very likely to be modified during the final design, as additional subsurface data become available.

Table 4-1. Location Of Borings

Boring	Easting	Northing	Boring	Easting	Northing	Boring	Easting	Northing
B1-1	1511292	566194	B2-4	1504773	543753	C3-5	1506102	526929
B1-2	1511010	560879	B2-5	1506055	550039	B4A-1	1528043	595226
B1-3	1513986	562380	C2-1	1503880	551675	B4A-2	1525572	589453
B1-4	1514811	567112	C2-2	1501772	547672	B4A-3	1527651	587934
B1-5	1512523	569734	C2-3	1504163	542261	B4A-4	1522938	584760
SB1-1	1510702	571494	C2-4	1508113	547671	C4A-1	1522031	587103
SB1-2	1511920	563846	C2-5	1508709	551933	C4A-2	1525817	584877
SB1-3	1506090	561719	B3-1	1502098	527612	C4A-3	1529131	592682
C1-1	1510430	569269	B3-2	1500693	522631	C4A-4	1529027	597710
C1-2	1508818	563405	B3-3	1503296	520612	B4B-1	1516104	585542
C1-3	1513877	558900	B3-4	1505085	525131	B4B-2	1513824	583095
C1-4	1516298	563907	B3-5	1502558	524453	C4B-1	1512742	581074
C1-5	1515028	569402	C3-1	1503660	529830	C4B-2	1518416	583872
B2-1	1506885	552649	C3-2	1499750	525404	C4B-3	1513902	585307
B2-2	1504375	547003	C3-3	1501111	518646			
B2-3	1502143	543921	C3-4	1505896	521891			

Note: Coordinates are in NAD83.

Table 4-2. Vane Shear Data

Boring No.	Tip Elevation (ft.)	Undisturbed		PI Corrected Factor	S Corrected Factor	Remolded			Sensitivity
		Torque (lbs)	S (psf)			Torque (lbs)	S (psf)	S Corrected	
Area 1									
B-1-1	-56.5	70	998	0.95	948	25	356	338	2.8
Area 2									
B-2-1	-40	25	356	0.75	267	22	314	235	1.1
B-2-2	-48	55	784	0.75	588	35	499	374	1.6
B-2-4	-62.5	10	143	0.75	107	0	0	0	>10
Area 3									
B-3-2	-49	55	784	0.75	588	45	641	481	1.2
B-3-3	-54	34	485	0.75	363	18	257	192	1.9
B-3-5	-60	35	499	0.75	374	23	328	246	1.5

Table 4-3. Summary Of Slope Stability Analysis

Site	Case	Depth Water	Bottom of Undercut	C psf	Dike		Berm			Factor of Safety
					Top	Slope	Length	Slope	Top Elev.	
1	1	-15	-15	SAND	+25	3H:1V	-	-	-	-
2	2A	-25	-35	300	+10	3H:1V	160	3H:1V	-10	1.27
	2B	-25	-35	300	+12	3H:1V	180	3H:1V	-10	1.30
	2C	-25	-35	300	+15	3H:1V	240	3H:1V	-10	1.28
	2D	-25	-35	400	+15	3H:1V	240	3H:1V	-10	1.48
	2E	-25	-35	400	+18	3H:1V	240	3H:1V	-10	1.35
	2F	-25	-35	400	+20	3H:1V	240	3H:1V	-10	1.27
3	3A	-25	-40	250	+8	3H:1V	120	5H:1V	-10	1.29
	3B	-25	-40	250	+12	3H:1V	180	5H:1V	-10	1.27
	3C	-25	-40	250	+15	3H:1V	240	5H:1V	-10	1.28
	3D	-25	-40	320	+15	3H:1V	240	5H:1V	-10	1.31
	3E	-25	-40	320	+16	3H:1V	240	5H:1V	-10	1.28
4A	4A-A	-20	-30	250	+8	3H:1V	160	5H:1V	-10	1.28
	4A-B	-20	-30	250	+12	3H:1V	220	5H:1V	-10	1.26
	4A-C	-20	-30	250	+15	3H:1V	280	5H:1V	-10	1.26
4B-1 North	4B1-A	-12	-20	---	+15	3H:1V	---	---	---	1.52
	4B1-B	-12	-20	---	+20	3H:1V	---	---	---	1.52
4B-2 South	4B2-A	-12	-20	250	+8	3H:1V	160	5H:1V	-10	1.28
	4B2-B	-12	-20	250	+12	3H:1V	240	5H:1V	-10	1.27
	4B2-C	-12	-20	250	+15	3H:1V	320	5H:1V	-10	1.29

Table 4-4. Summary Of Volume Data

Area	Dike			Berm				Volume CY/LF
	Top	Bottom	Slope	Top	Bottom	Slope	Length	
1	+25	-15	3H:1V	-	-	-	-	250
2	+10	-10	3H:1V	-10	-35	3H:1V	160	550
	+12	-10	3H:1V	-10	-35	3H:1V	180	605
	+15	-10	3H:1V	-10	-35	3H:1V	240	750
3	+8	-10	3H:1V	-10	-40	5H:1V	120	620
	+12	-10	3H:1V	-10	-40	5H:1V	180	800
	+15	-10	3H:1V	-10	-40	5H:1V	240	970
4A	+8	-10	3H:1V	-10	-30	5H:1V	160	450
	+12	-10	3H:1V	-10	-30	5H:1V	220	575
	+15	-10	3H:1V	-10	-30	5H:1V	280	695
4B-1	+15	-20	3H:1V	N/A	N/A	N/A	N/A	160
	+20	-20	3H:1V	N/A	N/A	NA/	N/A	200
4B-R	+8	-20	3H:1V	-10	-20	5H:1V	160	230
	+12	-20	3H:1V	-10	-20	5H:1V	240	320
	+15	-20	3H:1V	-10	-20	5H:1V	320	400

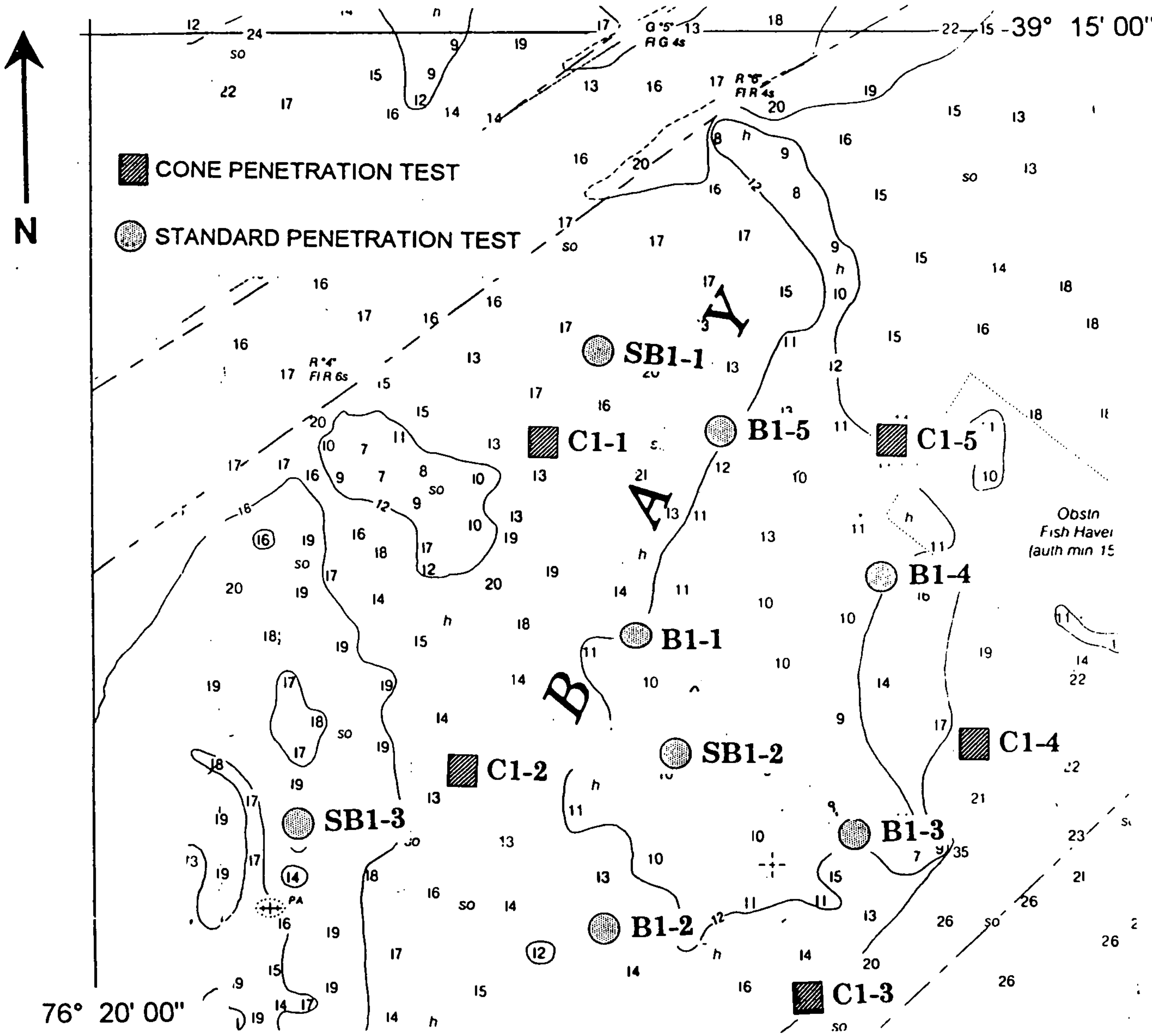


Figure 4-1. Boring Location Plan - Site 1

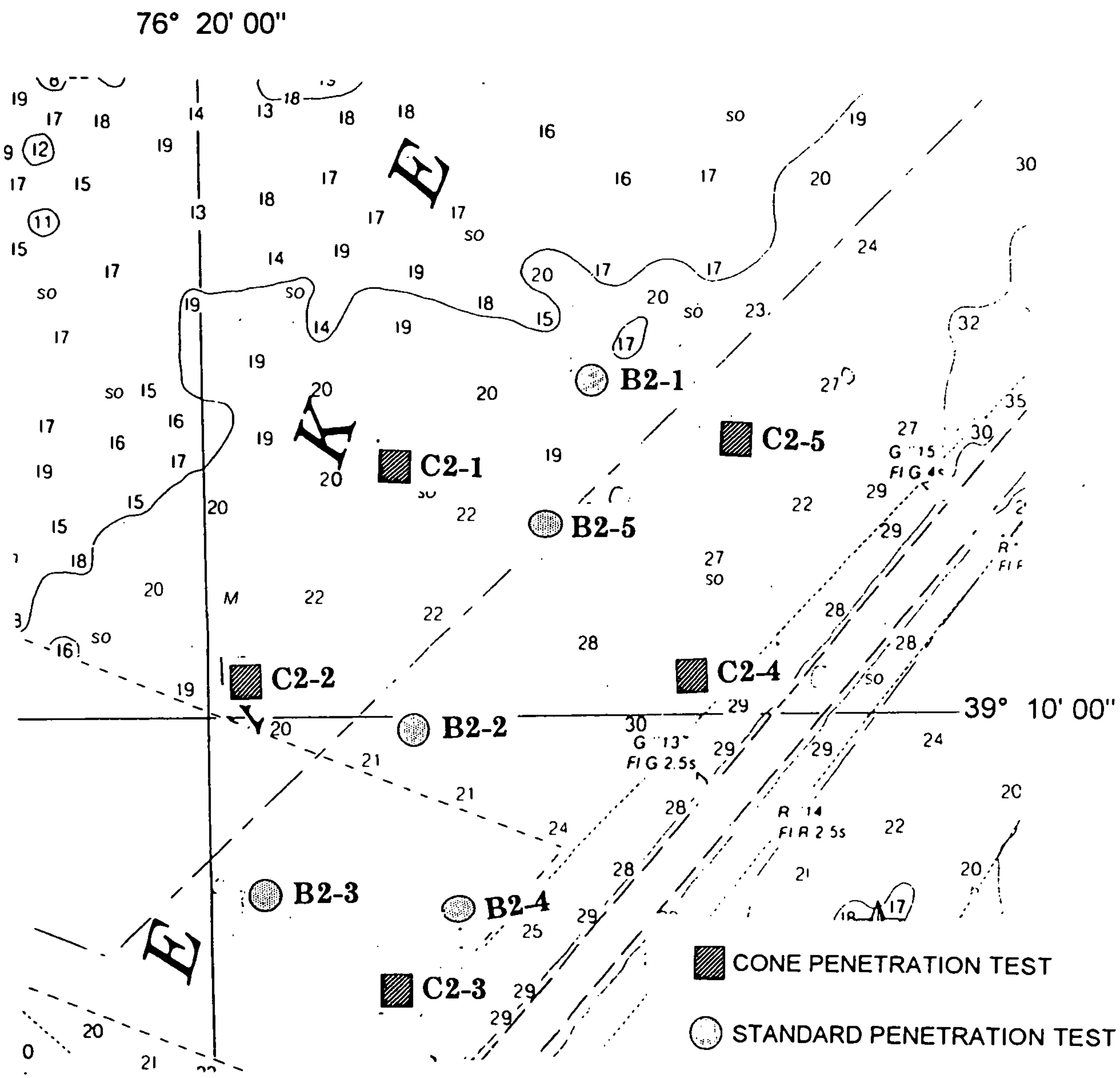


Figure 4-2. Boring Location Plan - Site 2

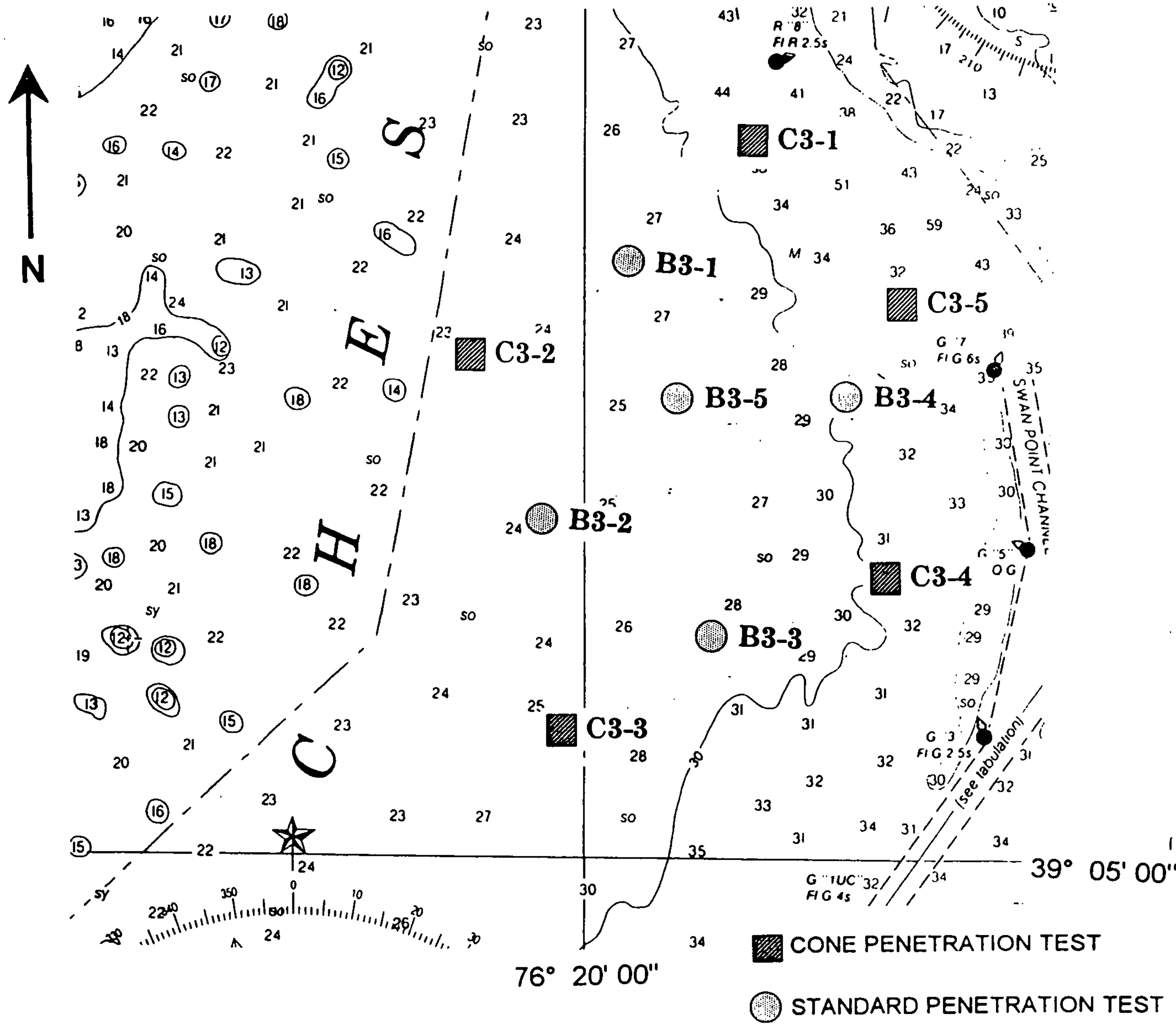


Figure 4-3. Boring Location Plan - Site 3

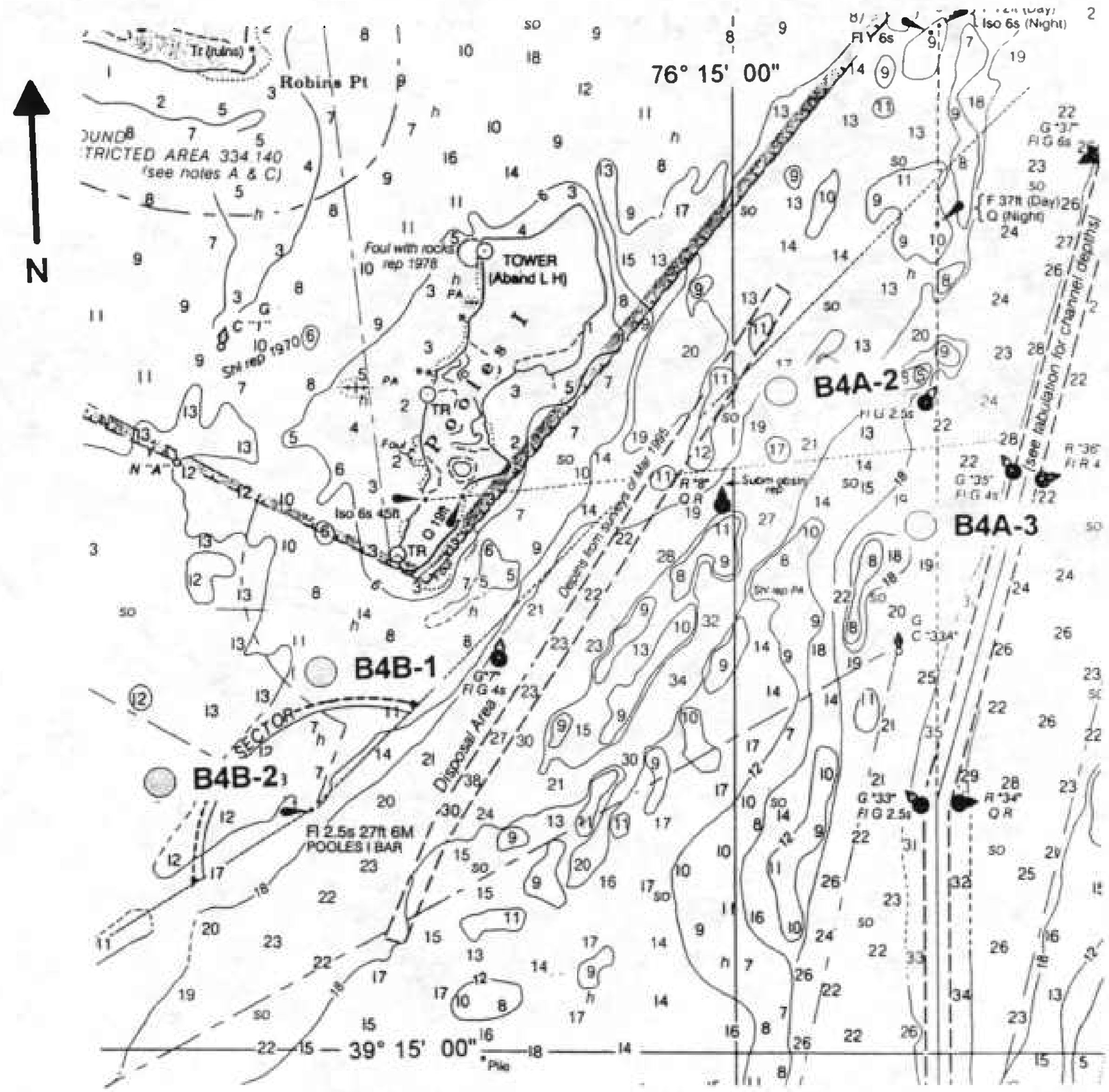


Figure 4-4. Boring Location Plan - Site 4

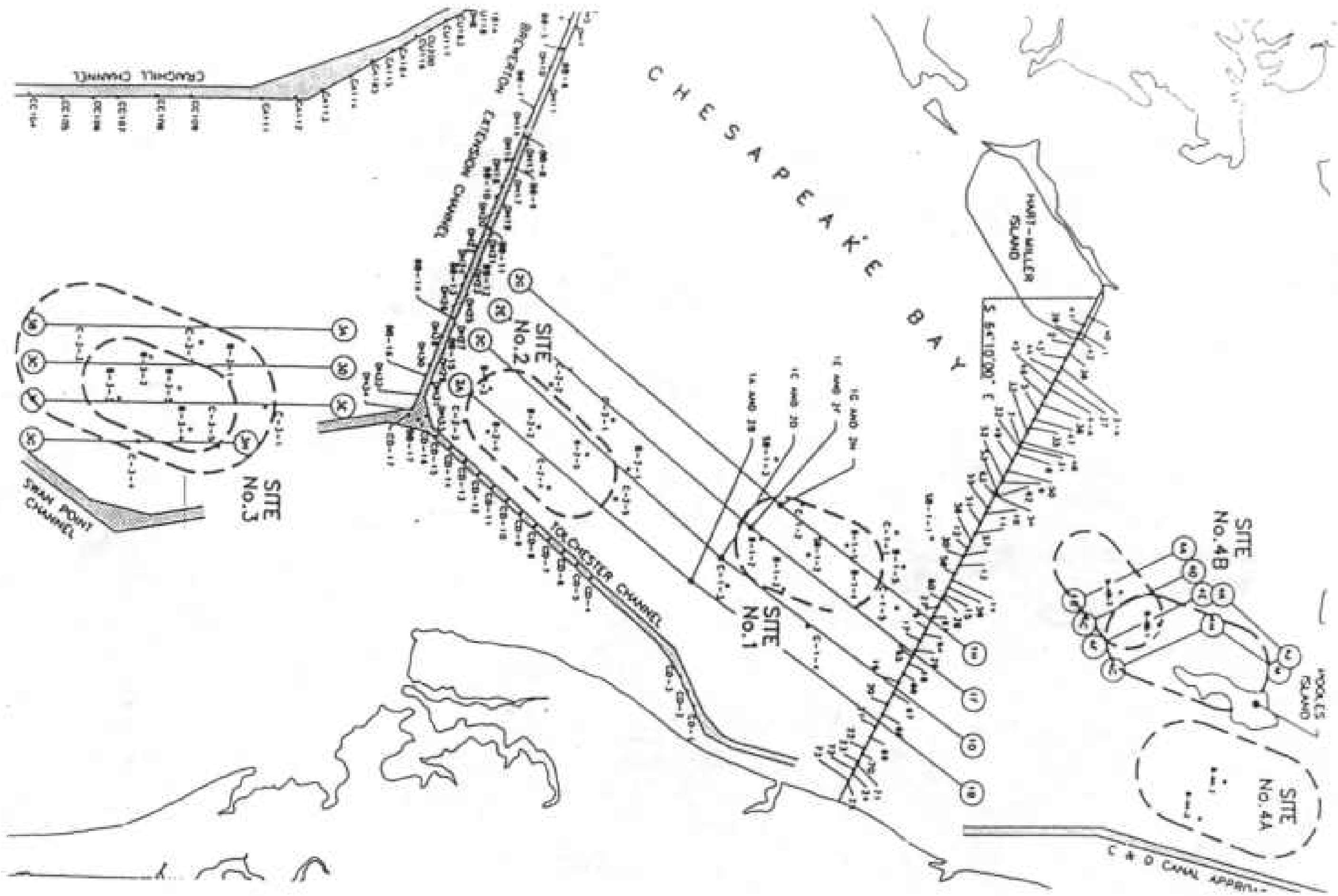
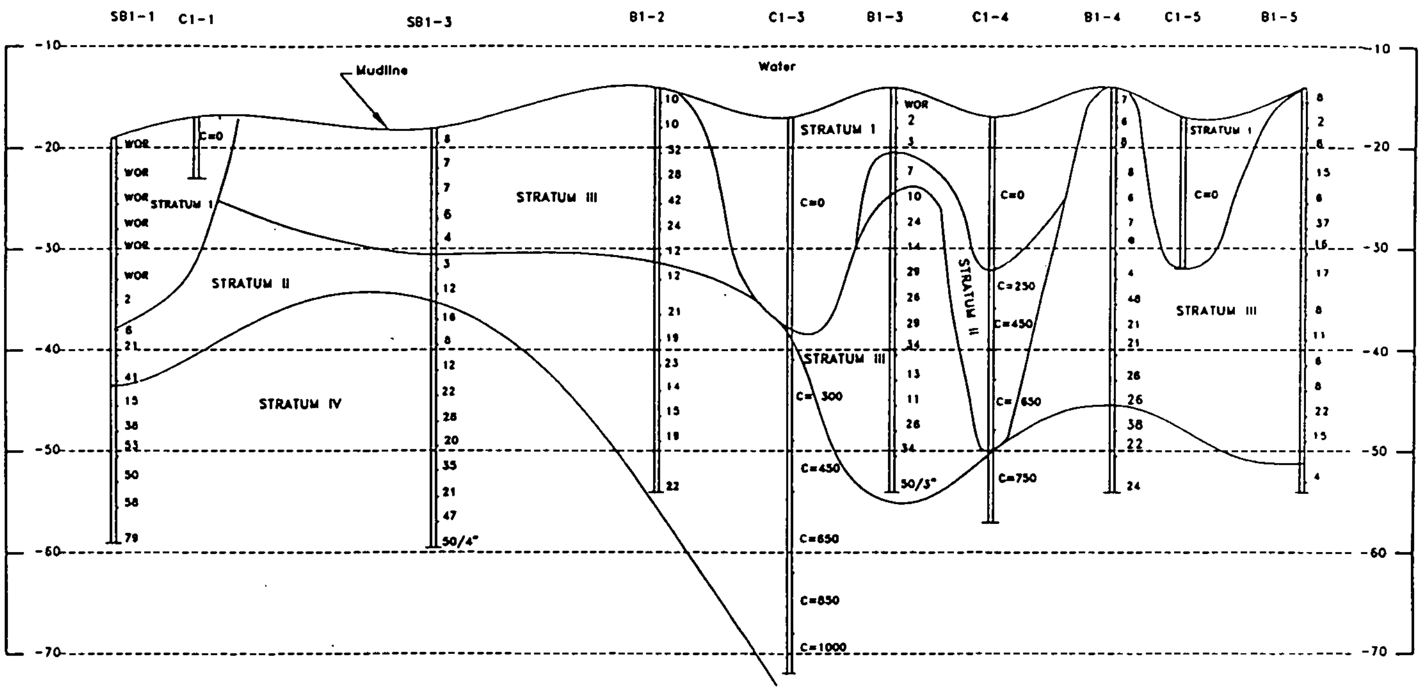


Figure 4-5. Boring & Acoustic Profile Location Plan



LEGEND

B1-1/C1-1- Boring Number/CPT Number

WOR - Weight of Rod
WOH - Weight of Hammer
10 - Standard Penetration Resistance, Blows/foot
C=0 - Cohesion in Psf, based on CPT

STRATUM I - Dark gray Silty CLAY
STRATUM II - Gray Silty CLAY
STRATUM III - Gray/brown Silty SAND
STRATUM IV - Gray/brown Silty SAND

Figure 4-6. Generalized Subsurface Profile Site 1 - Perimeter

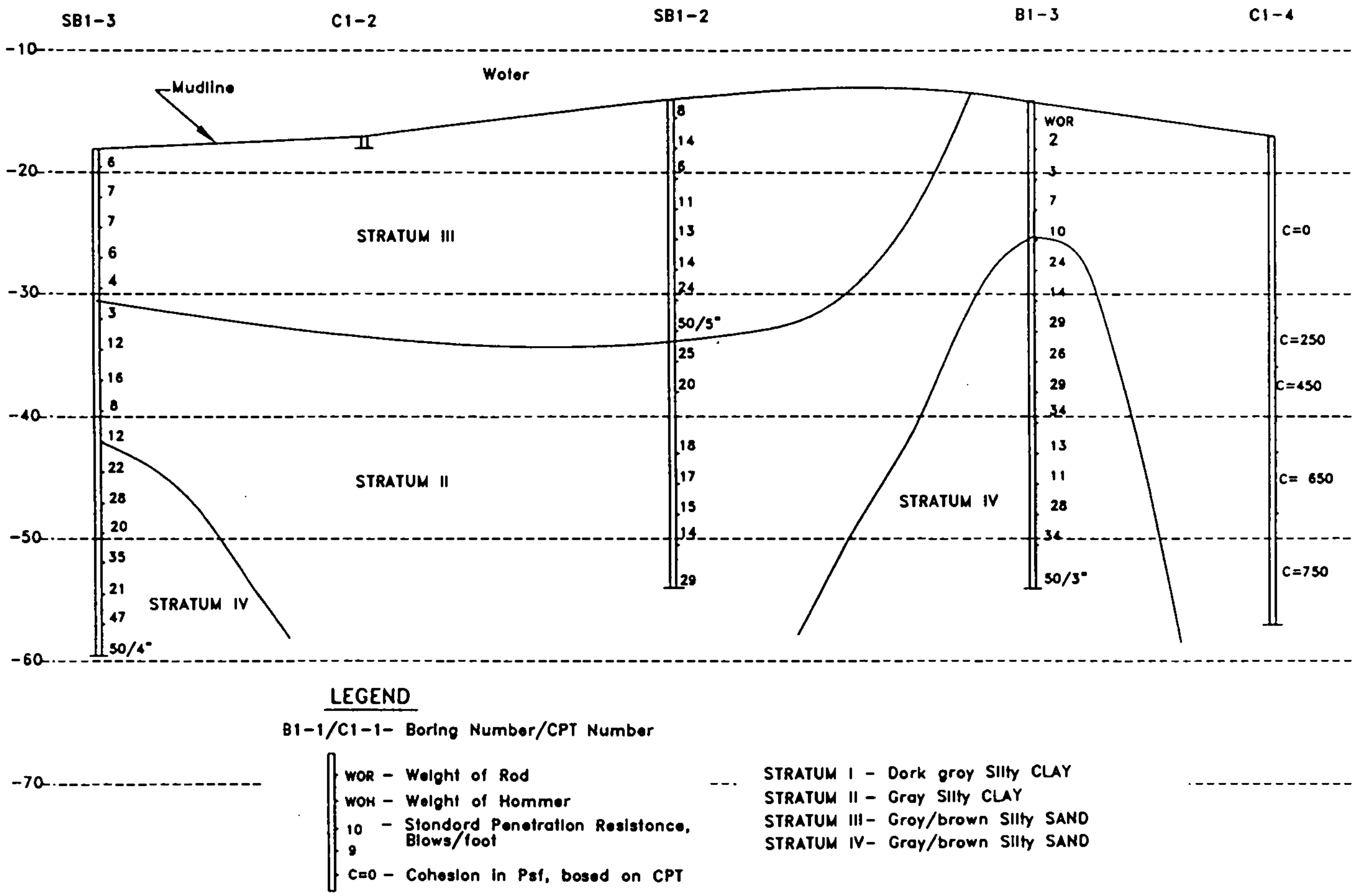


Figure 4-7. Generalized Subsurface Profile Site 1 - Section A-A

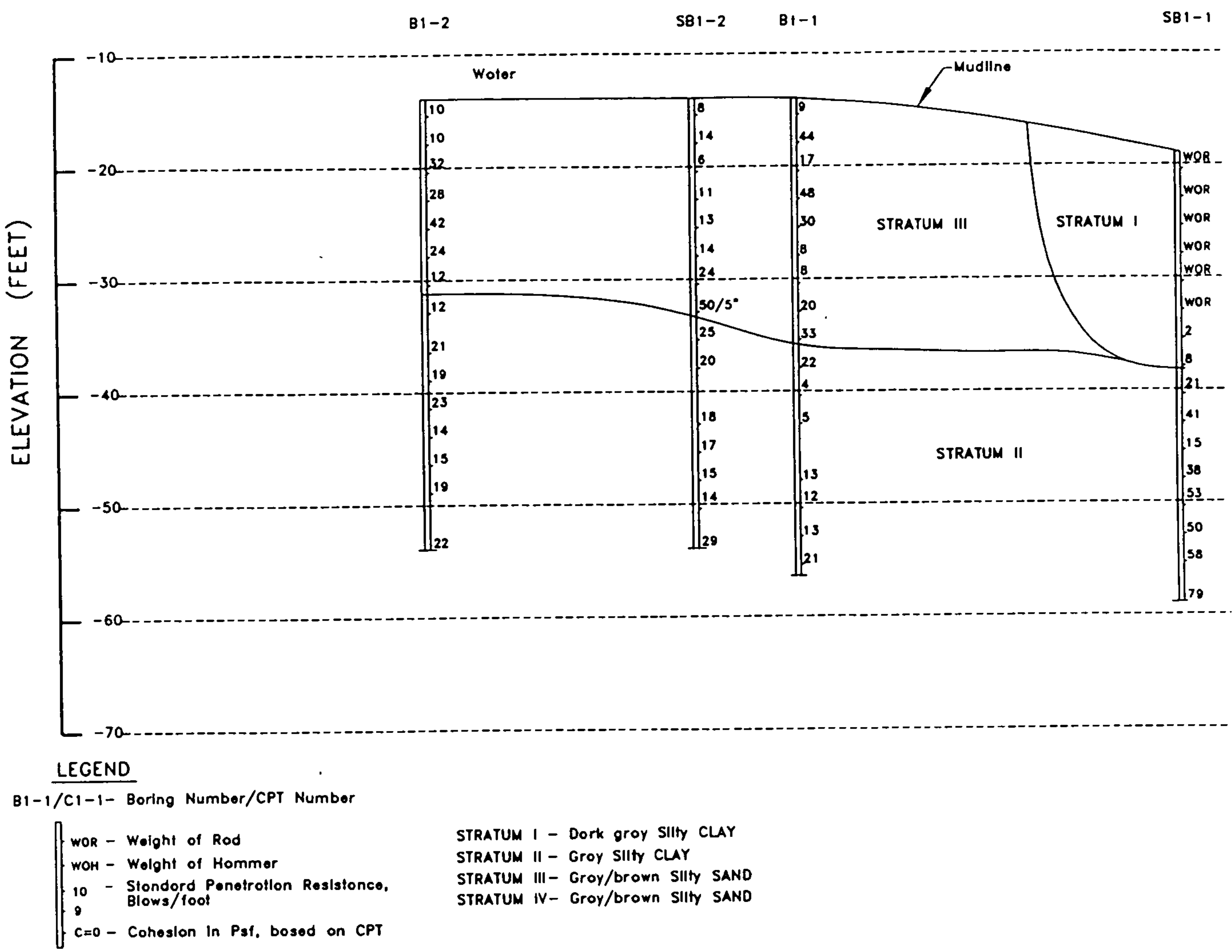


Figure 4-8. Generalized Subsurface Profile Site 1 - Section B-B

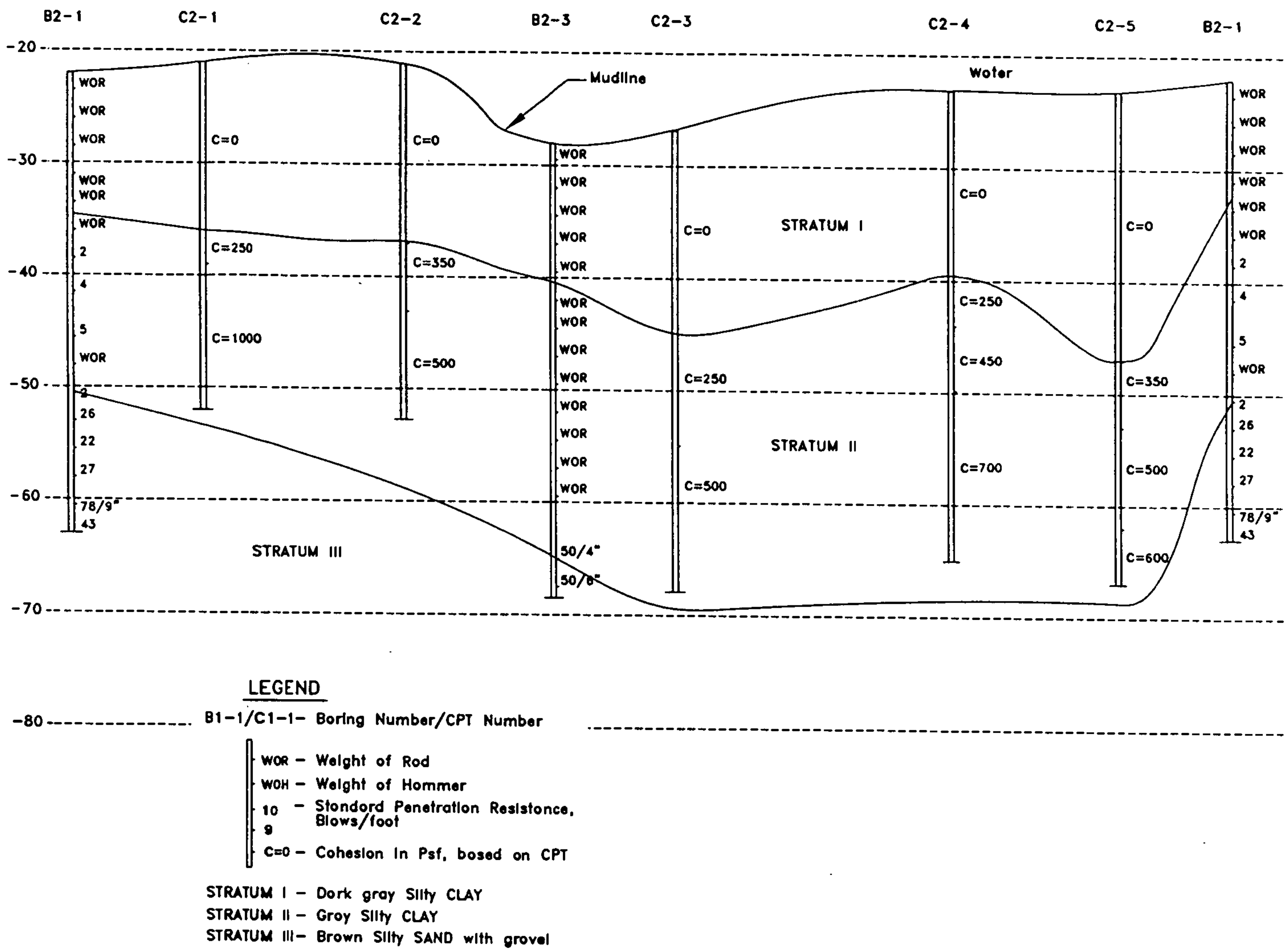
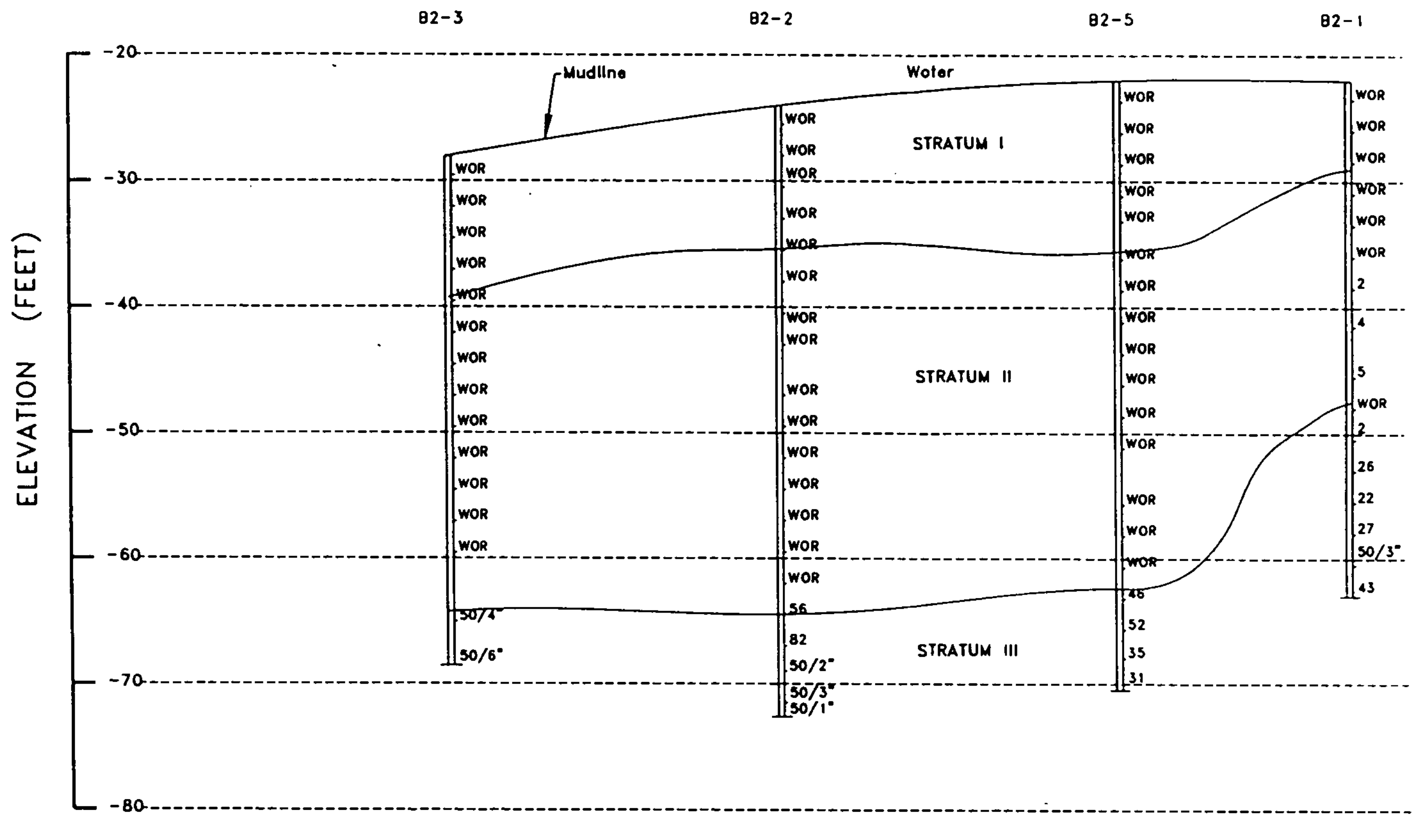


Figure 4-9. Generalized Subsurface Profile Site 2 - Perimeter



LEGEND

B1-1/C1-1- Boring Number/CPT Number

WOR - Weight of Rod
WOH - Weight of Hammer
10 9 - Standard Penetration Resistance, Blows/foot
C=0 - Cohesion in Psf, based on CPT

STRATUM I - Dark gray Silty CLAY
STRATUM II - Gray Silty CLAY
STRATUM III- Brown Silty SAND with gravel

Figure 4-10. Generalized Subsurface Profile Site 2 - Section A-A

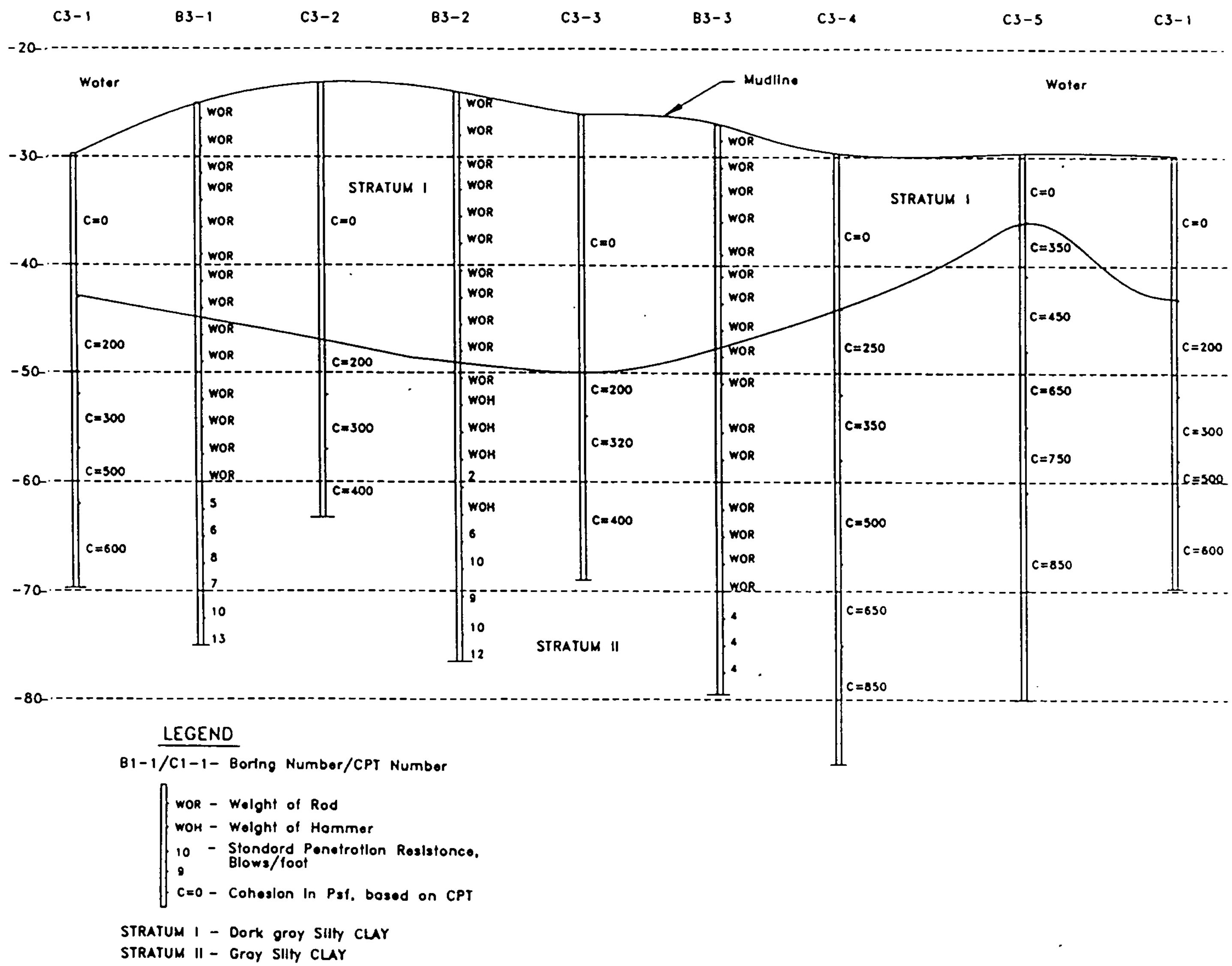


Figure 4-11. Generalized Subsurface Profile Site 3 - Perimeter

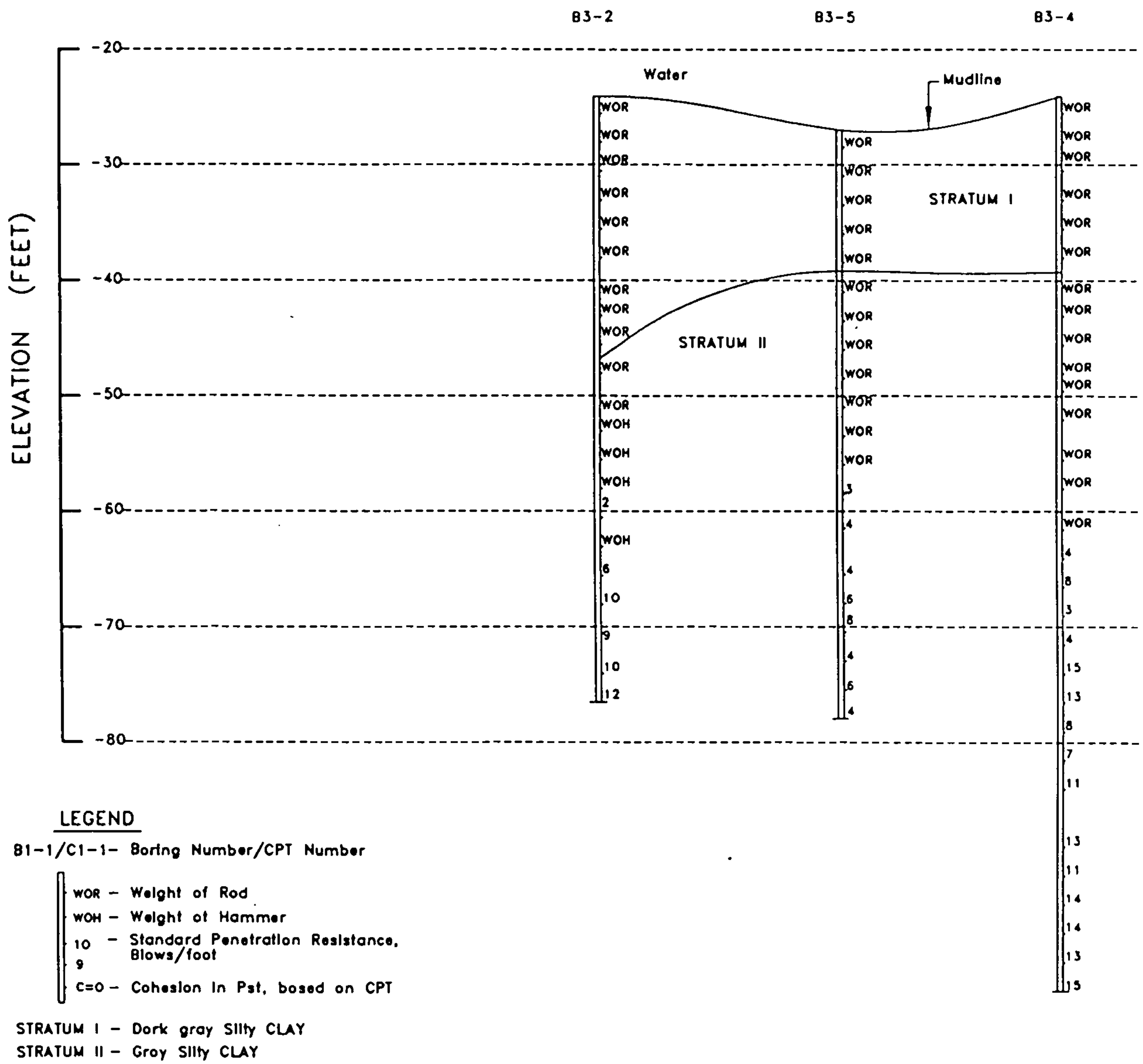
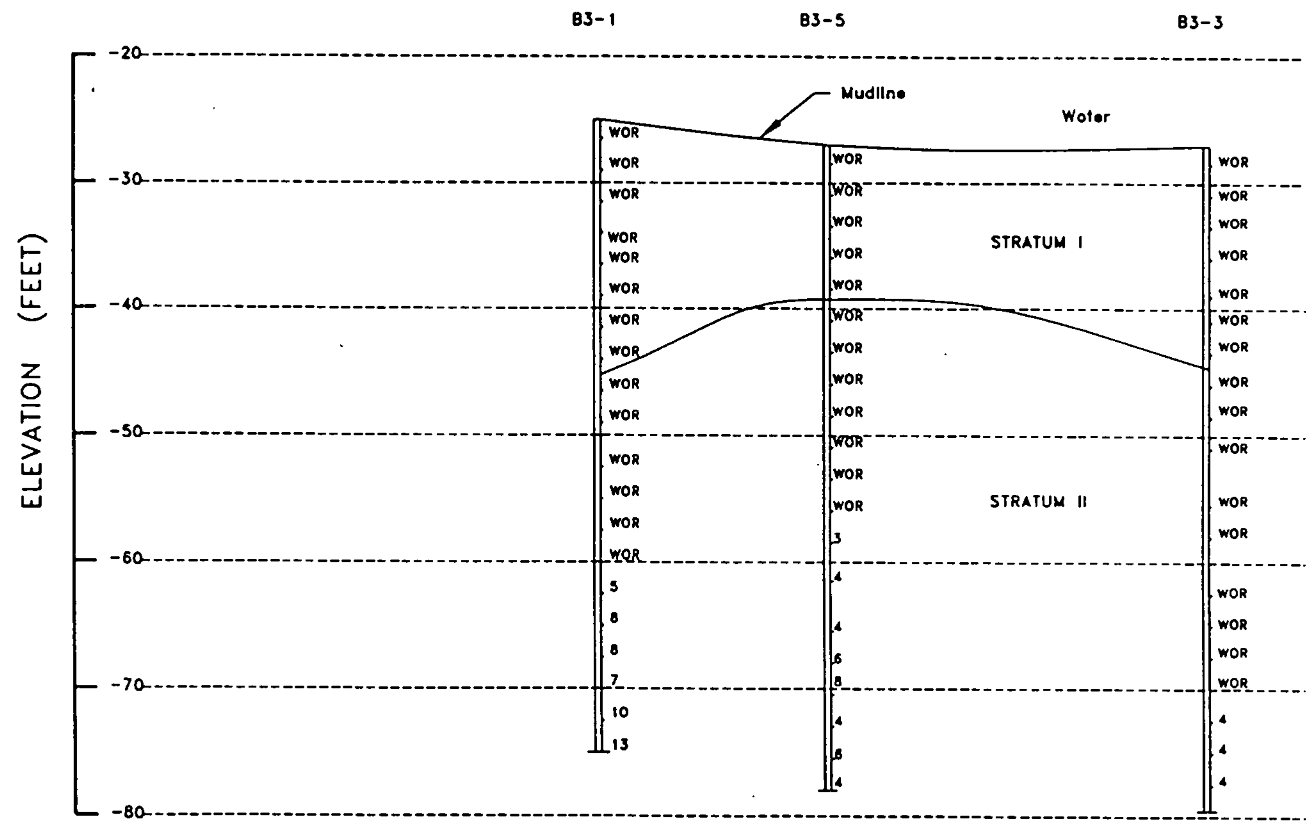


Figure 4-12. Generalized Subsurface Profile Site 3 - Section A-A



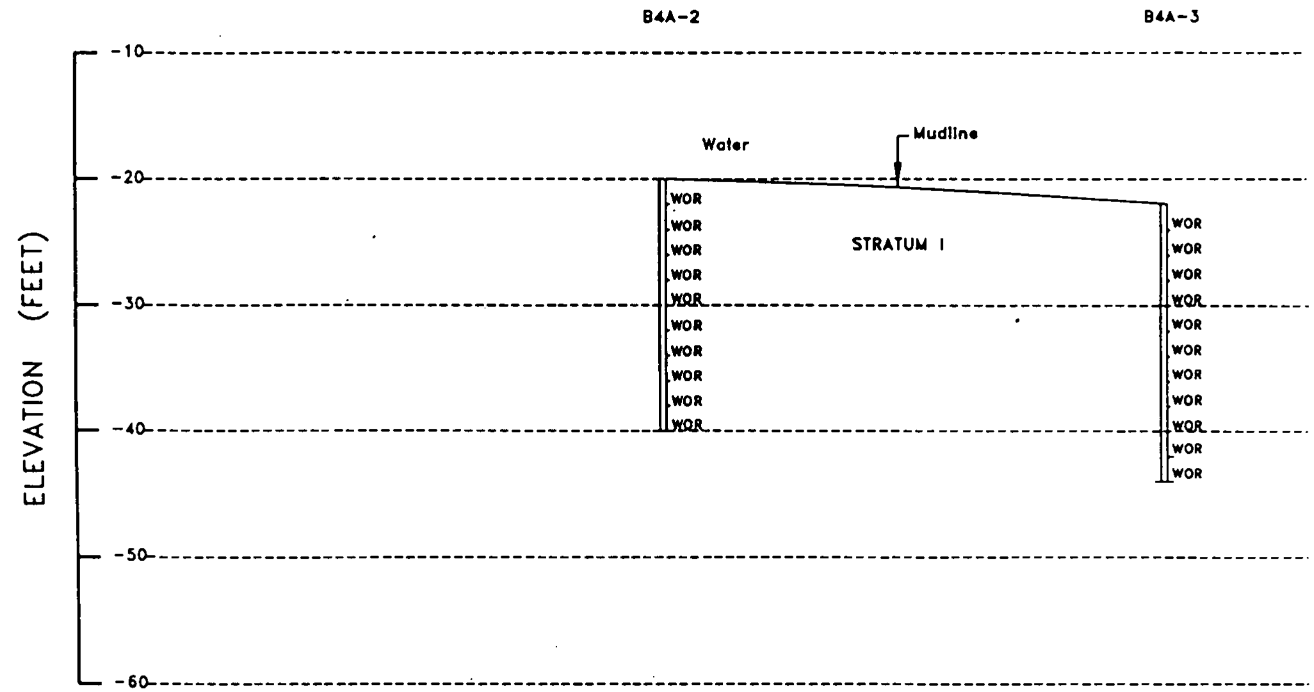
LEGEND

B1-1/C1-1- Boring Number/CPT Number

WOR - Weight of Rod
WOH - Weight of Hammer
10
9 - Standard Penetration Resistance, Blows/foot
C=0 - Cohesion in Psf, based on CPT

STRATUM I - Dark gray Silty CLAY
STRATUM II - Gray Silty CLAY

Figure 4-13. Generalized Subsurface Profile Site 3 - Section B-B



LEGEND

B1-1/C1-1- Boring Number/CPT Number

WOR - Weight of Rod

WOH - Weight of Hammer

10 - Standard Penetration Resistance, Blows/foot

9

C=0 - Cohesion in Psf, based on CPT

STRATUM I - Dark gray Silty CLAY/Clayey SILT

Figure 4-14. Generalized Subsurface Profile Site 4A

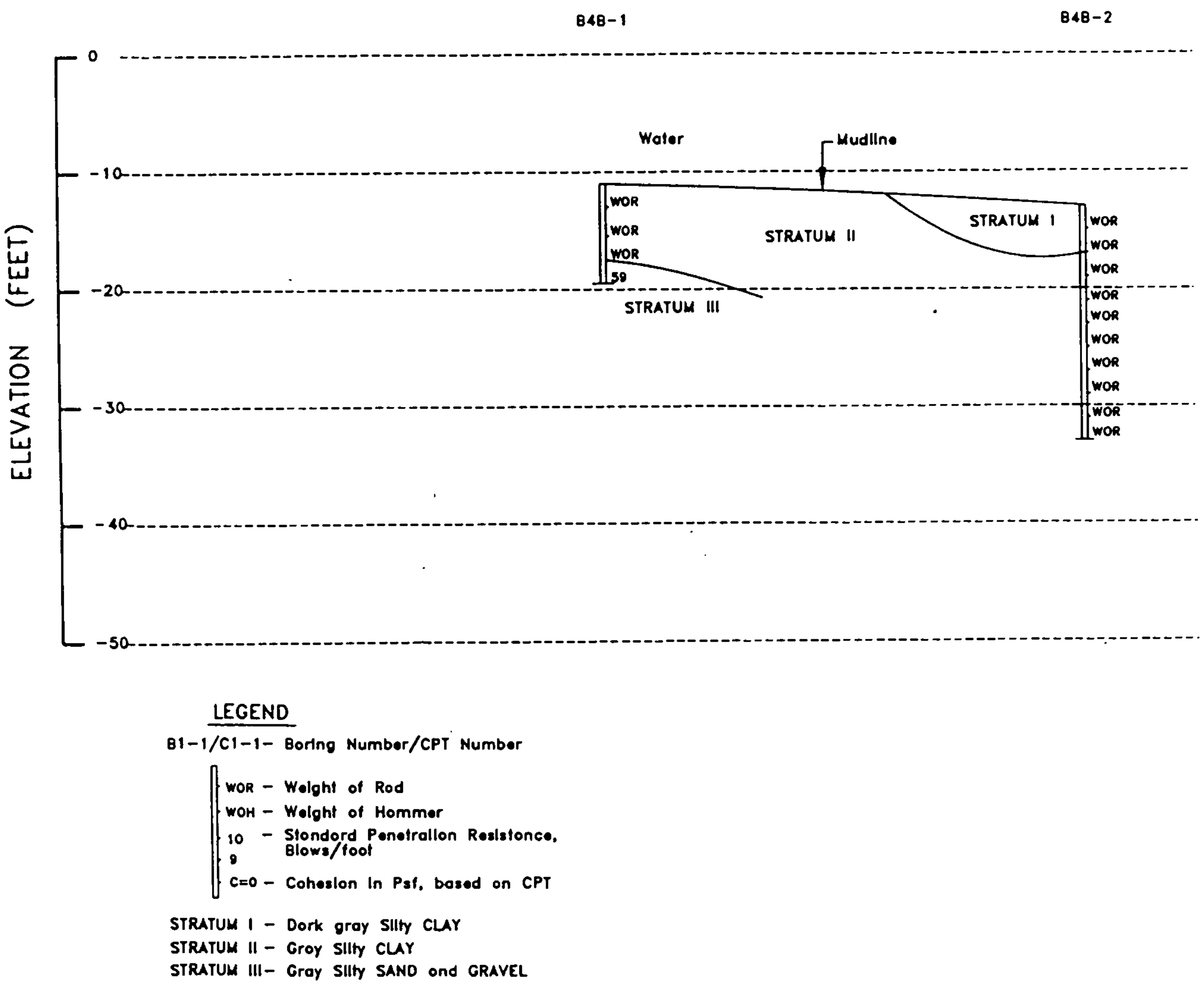


Figure 4-15. Generalized Subsurface Profile Site 4B

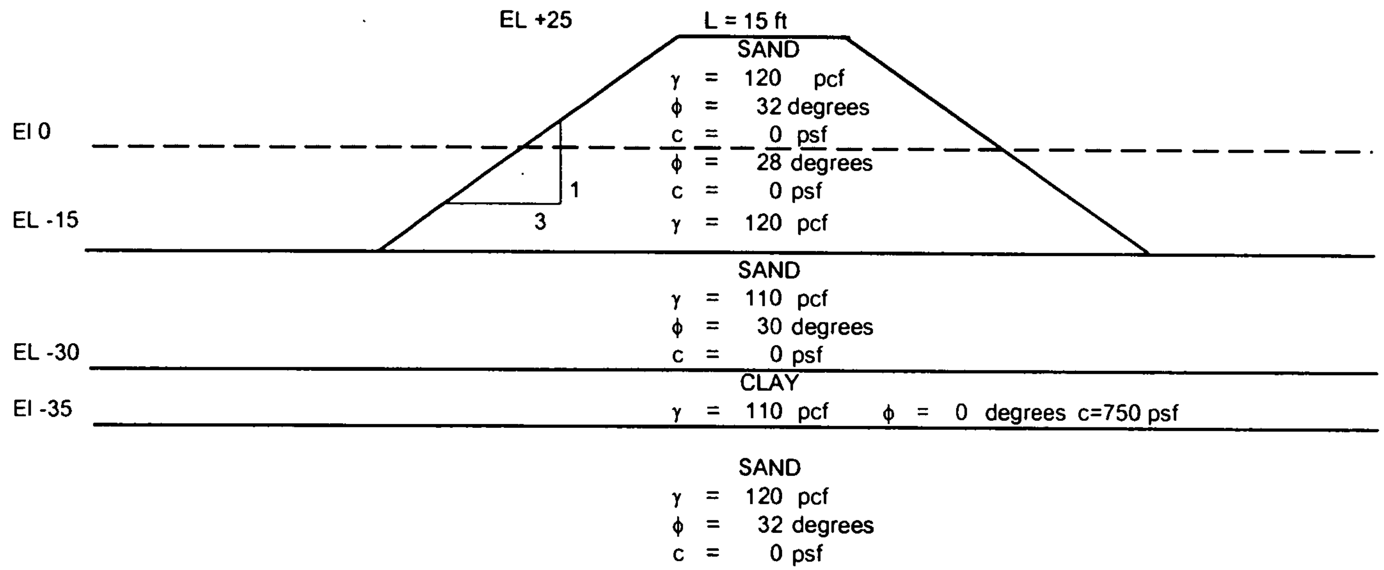


Figure 4-16. Recommended Dike Section Site 1 - El. +25

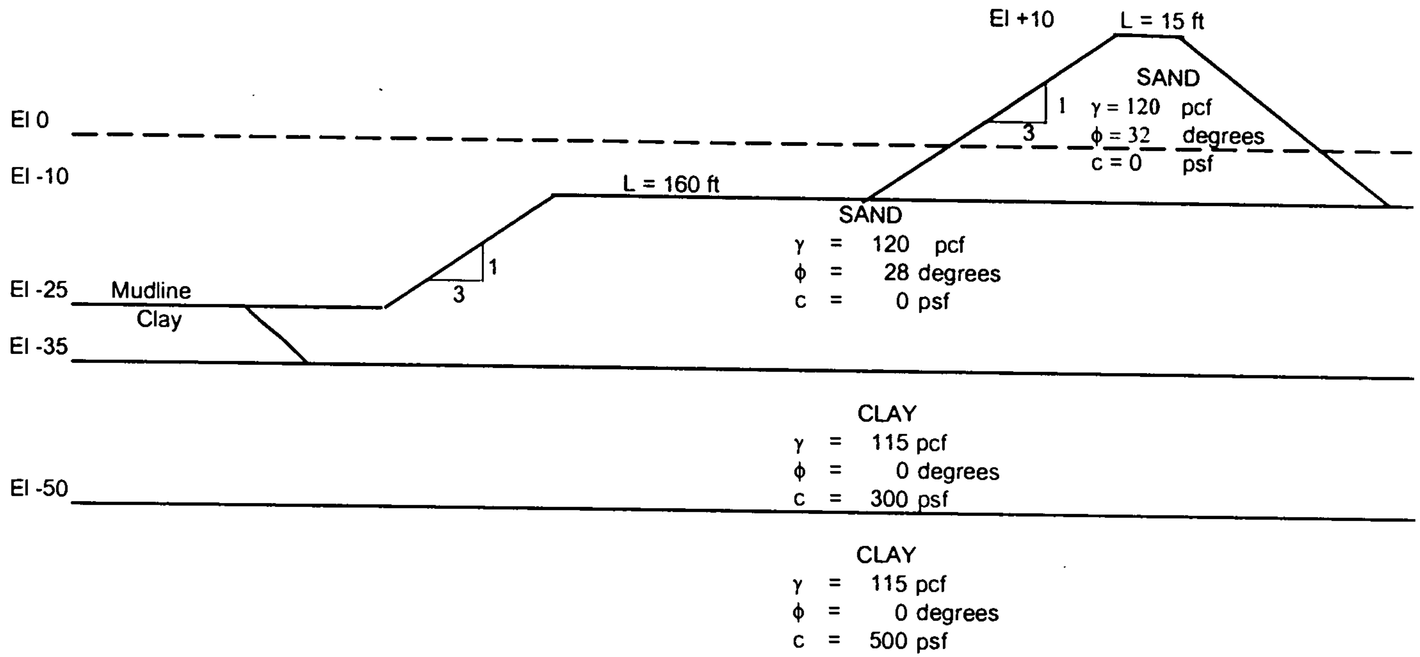


Figure 4-17. Recommended Dike Section Site 2 - El. +10

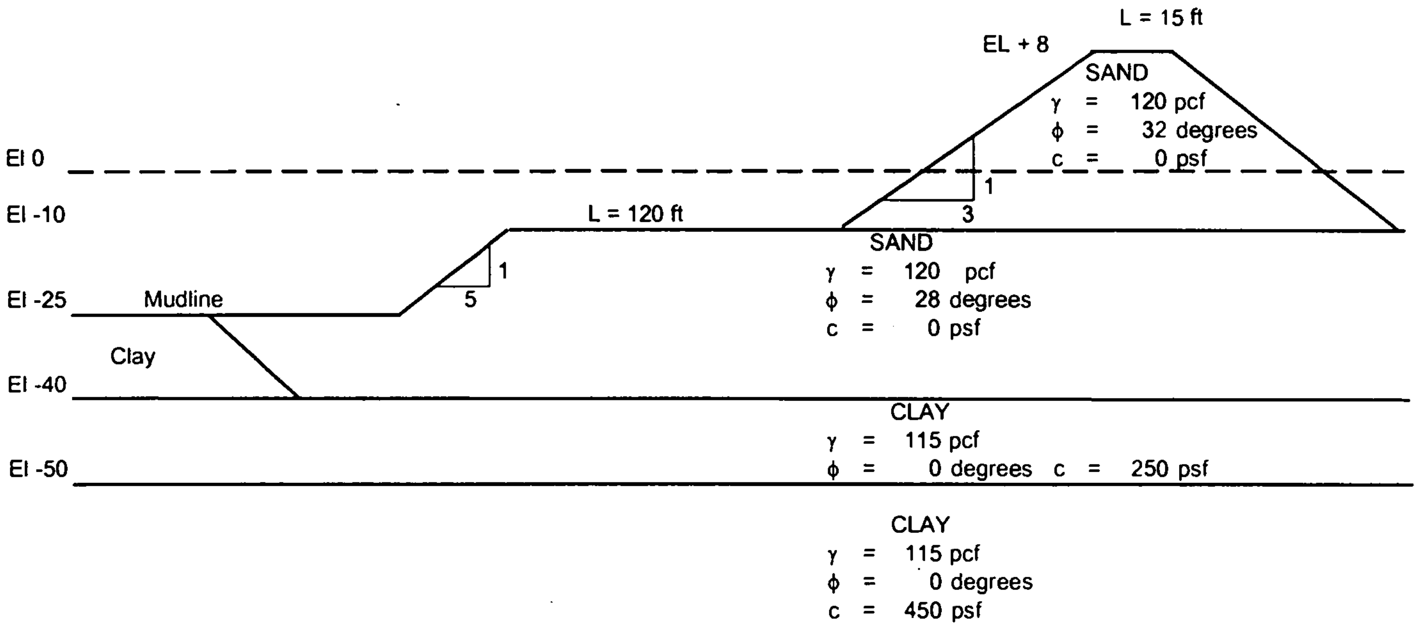


Figure 4-18. Recommended Dike Section Site 3 - El. +8

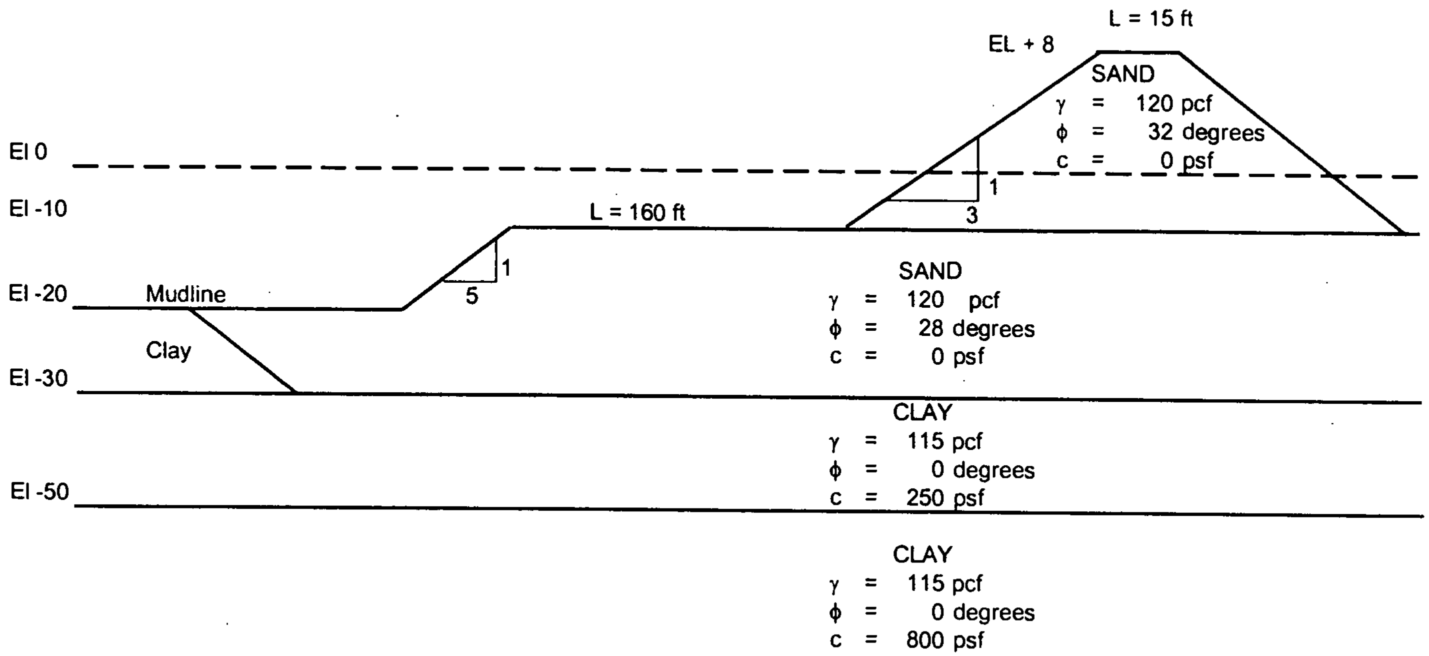


Figure 4-19. Recommended Dike Section Site 4A - El. +8

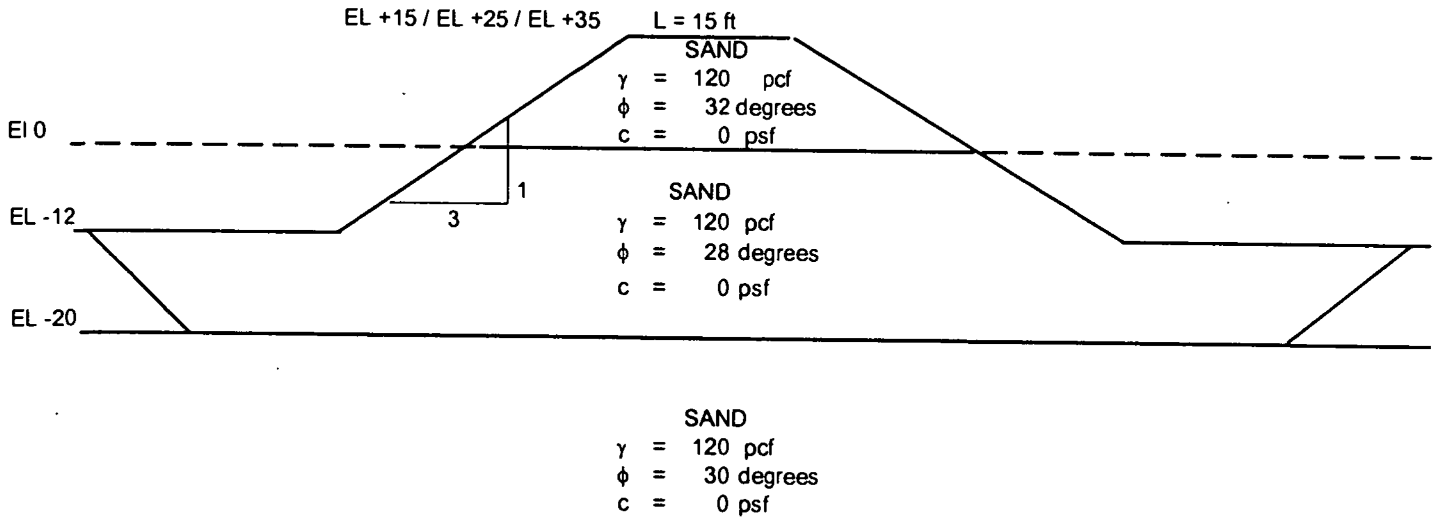


Figure 4-20. Recommended Dike Section Site 4B

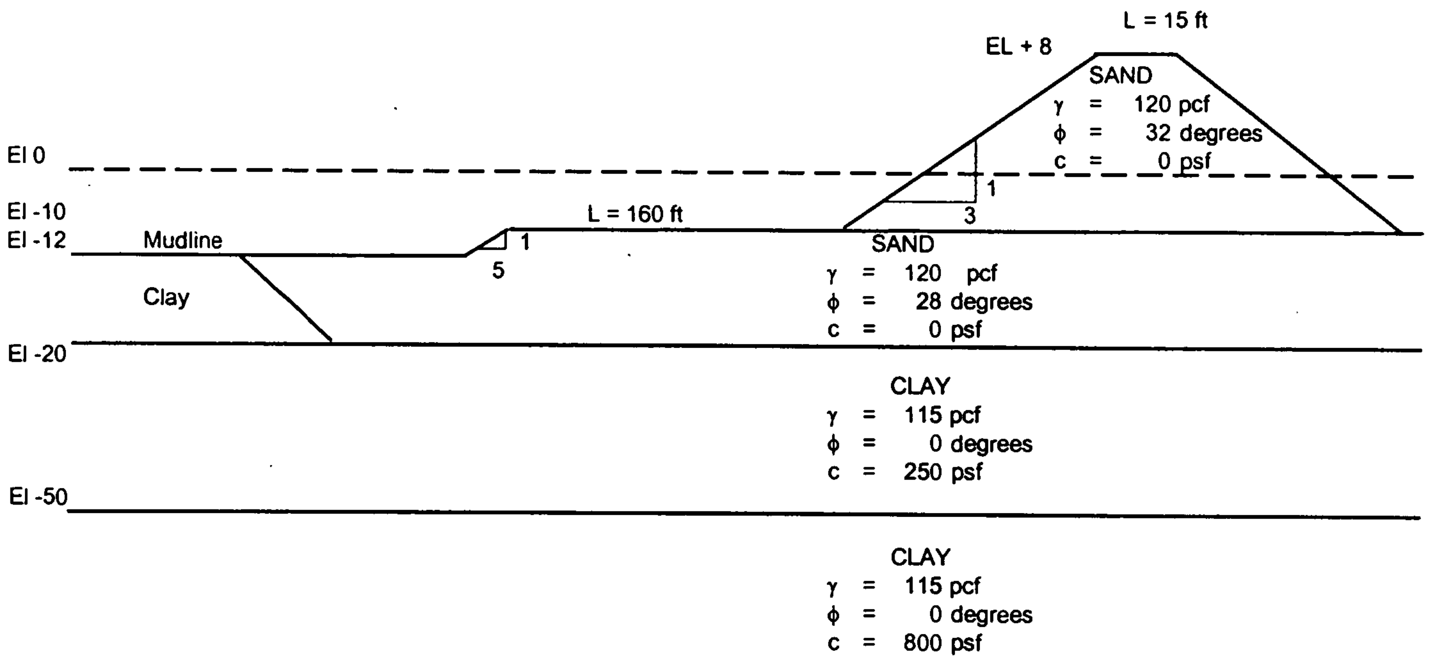


Figure 4-21. Recommended Dike Section Site 4B-R - El. +8

5.0 COASTAL ENGINEERING INVESTIGATION

5.1 Water Levels

Normal water level variations in the upper bay are generally dominated by astronomical tides, although wind effects and freshwater discharge can be important. Extreme water levels, on the other hand, are dictated by storm tides.

5.1.1 Astronomical Tides

Astronomical tides in the Upper Chesapeake Bay are semi-diurnal. The mean tide level is between 0.6 and 0.9 ft above MLLW; the mean tidal range is between 0.9 and 1.2 ft and the spring tidal range is between 1.1 and 1.8 ft (NOS 1997). Tidal datum characteristics for several locations in the upper bay reported from National Ocean Service are presented in Table 5-1. The difference in elevation between MLLW and national geodetic vertical datum (NGVD) is approximately 0.3 ft for the upper bay region. MLLW will serve as the datum for this project.

5.1.2 Storm Surge

Design water levels for the five study site sites are dominated by storm effects (i.e. storm surge and wave setup) in combination with astronomical tide. Storm surge is a temporary rise in water level generated either by large-scale extra-tropical storms known as northeasters, or by hurricanes. The rise in water level results from wind action, the low pressure of the storm disturbance and the Coriolis force. Wave setup is a term used to describe the rise in water level due to wave breaking. Specifically, change in momentum that attends the breaking of waves propagating towards shore results in a surf zone force that raises water levels at the shoreline.

A comprehensive evaluation of storm-induced water levels for several Chesapeake Bay locations has been conducted by the Virginia Institute of Marine Science (1978) as part of the Federal Flood Insurance Program. Results of this study are summarized in the water-level vs. frequency curves presented in Figure 5-1 which provide water levels in ft above NGVD for various return periods. Data in Figure 5-1 are for the closest station location for the upper bay, Tolchester Beach on the eastern shore, about 2 miles due east of Site 1. Figure 5-1 indicates that the storm tide elevation for a 25-year return period is 5.7 ft MLLW (5.4 ft NGVD) and the 100-year water level for the project site is 9.1 ft MLLW (8.8 ft NGVD). As a means of comparison, the 25-year return period elevations for Baltimore and Annapolis are 5.4 MLLW (5.1 ft NGVD) and 5.1 ft MLLW (4.8 ft NGVD), respectively.

5.2 Wave Analysis

5.2.1 Wind Conditions

Wind data from the NOAA, National Climatic Data Center (NOAA 1982) for Baltimore-Washington International (BWI) Airport, were used in estimating wind conditions at the five project sites. The BWI data is presented in Table 5-2 as fastest mile winds which are defined as the highest recorded wind speeds that last long enough to travel one mile during a 24 hour recording period. For example, a fastest mile wind speed of 60 miles per hour (mph) would have a duration of 60 seconds, a fastest mile wind speed of 50 mph would have a duration of 72 seconds, etc. The wind data presented in Table 5-2 was used to develop wind speed-return period relationships based on a Type I (Gumbel) distribution. Return period is defined as the average time between wind events which equal or exceed a given value. The specific return periods examined were 5, 10, 15, 20, 25, 30, 35, 40, 50 and 100 years.

Annual extreme windspeeds for the period 1951 through 1982 provided in Table 5-2 are for eight directions; namely: North (N), Northeast (NE), East (E), Southeast (SE), South (S), Southwest (SW), West (W) and Northwest (NW).

A review of the wind speed data indicate that during the 32-year period from 1951 through 1982, six wind events exceeded 60 mph. In order to quantify the frequency of various wind events, statistical analyses of the wind data were performed. These analyses consisted of fitting external statistical distributions through the annual extreme wind speeds for each of the wind directions and all of the directions. The wind statistics for each direction (design wind speeds) are presented in Table 5-3 in terms of fastest mile wind speeds for various return periods. An additional direction, South-Southwest (SSW), was included because it is the longest fetch distance to all five sites; the wind speeds were taken as an average of south and southwest winds. Table 5-3 shows that the design wind speeds for a 25-year return period storm range from 47 mph for the east direction to 70 mph for the southwest direction. The design wind speeds presented in Table 5-3 have been used to estimate design wave conditions for the five project sites.

5.2.2 Wave Conditions

The five sites are exposed to wind-generated waves approaching from all directions. The longest fetch distances to which the site is exposed correspond to the south-southwest. In accordance with procedures recommended by the U.S. Army Shore Protection Manual (1984), a radially averaged fetch distance was computed for each direction. Wave conditions were hindcast along each fetch direction for the design winds presented in Table 5-3 (adjusted appropriately for duration), the water levels presented in Fig. 5-1, and the mean water depths along the nine fetch directions. Specifically, waves were hindcast for nine directional design wind speeds (i.e. the design wind speeds computed for each individual directions) using methods published in the Shore Protection Manual (1984).

A sea state is normally composed of a spectrum of waves with varying heights and periods which may range from relatively long waves to short ripples. In order to summarize the spectral characteristics of a sea state it is customary to represent that wave spectrum in terms of a distribution of wave energy over a range of wave periods. Having made this distribution, known as a wave spectrum, it is convenient to represent that wave spectrum by a single representative wave height and period. The wave conditions computed in the hindcast are the significant wave height and peak spectral wave period. The significant wave height is defined as the average of the highest one-third of the waves in the spectrum. Depending on the duration of the storm condition represented by the wave spectrum, maximum wave heights may be as high as 1.8 to 2 times the significant wave height. The peak spectral period is the wave period that corresponds to the maximum wave energy level in the wave spectrum.

The highest waves are estimated for the south-southwest direction. The 100-year return period waves for this direction have significant heights of 5.5, 5.5, 5.8, 5.5, and 5.5 ft and peak spectral wave periods of 4.8, 4.9, 5.0, 4.9 and 4.9 seconds for sites 1, 2, 3/3-S, 4A and 4B/4B-R, respectively. The 25-year return period significant wave heights are 10.7, 10.8, 11.5, 10.6 and 10.6 ft and the peak spectral wave periods are 6.4, 6.4, 6.6, 6.5, and 6.5 seconds for sites 1, 2, 3, 4A, and 4B/4B-R.

The above wave heights represent deep water conditions some distance offshore of the proposed dike alignments. Some sections of the dikes may be located in water having depths shallow enough to allow for some breaking of the waves, especially for higher return period events. The geotechnical investigation being conducted shows that four of the five sites (2, 3, 4A, and 4B), including the deeper sites (2, 3, and 4A) will require construction of a foundation berm to support the dike structure. This foundation berm would serve to reduce the water depths and affect wave heights of the structures.

Discussions presented above indicate that waves in the deep water wave spectrum may be as much as twice the offshore significant wave height and the dike structures could be exposed to some breaking waves. The random wave analyses of Goda (1985) has been used to examine the maximum breaking and maximum significant waves which can reach the dikes. The first step in examining wave conditions for a given bottom elevation and water level is to compute the total water depth from which the maximum breaking wave height can be determined. This breaker depth is the sum of the selected water elevation above MLLW and the bottom elevation below MLLW. The maximum breaker height that can be supported in the resulting water depth is computed using formulae published in the Shore Protection Manual (1984).

Goda's analyses requires the estimate of an equivalent offshore significant wave height (also referred to as the equivalent unrefracted wave height) which is computed from the maximum breaking wave height and the linear shoaling coefficient using equations published by Goda (1985). Similar equations are available for computing significant wave height, and the results are used to compute the nearshore significant and maximum wave heights.

The computed hindcast indicates that nearshore significant wave heights from the south-southwest 5.5, 5.5, 5.8, 5.5, and 5.5 ft for a 5-year storm for sites 1, 2, 3/3-S, 4A, and 4B/4B-R respectively. These values are the same as the offshore significant wave heights, i.e., minimal wave breaking occurs. Similarly, nearshore significant waves from the south-southwest are 8.9, 8.2, 8.2, 8.2, and 9.0 for sites 1, 2, 3/3-S, 4A, and 4B/4B-R, respectively. These values are lower than the offshore significant wave heights, indicating that wave breaking occurs for a 100-year event. Maximum depth limited or breaking waves from the south-southwest are computed to be 9.3, 9.5, 9.6, 9.6, and 9.9 ft for sites 1, 2, 3/3-S, 4A, and 4B/4B-R, respectively for a 5-year storm and 14.6, 13.5, 13.6, 13.6 and 14.7 ft for sites 1, 2, 3/3-S, 4A, and 4B/4B-R, respectively, for a 100-year storm.

5.3 Dike Protection Design

5.3.1 Introduction

The principal components of a coastal protection dike include:

- Toe Protection
- Protective Revetment
- Berm (if needed)
- Upper Slope
- Crest Area and Roadway
- Dike Core

Toe protection is normally an integral part of the revetment structure and is designed to prevent that structural component from undermining as a result of wave and/or current-induced scour. The protective revetment serves to hold the dike core in place and is often comprised of several layers of rock armoring. A berm may or may not be needed in the dike cross section. Where included, a berm can be used to limit wave runup and overtopping. The berm can also be used to minimize the armoring requirements for the revetment and upper slope of the dike. Roadways are often included on dikes in order to provide access to hinterland areas and access for repairs to the dikes.

The dike geometry used for this prefeasibility study is comprised of toe protection, a rubble mound revetment (i.e. the side slope), a horizontal crest with a crushed stone roadway and a core constructed of sand. One of the more important variables of the dike design is the side slope which, together with the crest height, is generally dictated by soil conditions and dike construction methodologies. Soil conditions and dike construction techniques are discussed later in this section.

Based on the analyses performed for this project, the optimal dike design has been determined to have an outer slope of 3H:1V and an inner side slope of 5H:1V.

5.3.2 Dike Design Life

The design life selected for the containment dikes is an important factor in the overall planning. It should be noted that project life for dike design is different than the life capacity of the site for storing dredged material. The former pertains to the life expectancy and costs of the containment dikes and is treated in this section of the report whereas the latter pertains to the period of time it takes to fill the dredged material placement site. As the state has a commitment to adequately maintain the dikes, the project design has included an optimization analysis that balances initial capital cost with long-term maintenance to select the most overall cost-effective design.

Previously, USACE would stipulate a project life of 50 years (ER-1110-2-1407 "Hydraulic Design of Coastal Shore Protection Projects"). This has now been superseded by the revised ER-1110-2-1407 (November 1990) which dictates that a fuller range of alternatives be studied to account for differences in cost of repair, periodic replacements and rehabilitation. The 50-year project life is consistent with the nature of routine coastal and hydraulic engineering projects that are designed to protect large areas of rural and urban infrastructure against flooding and/or wave-induced damages. Furthermore, such projects are normally justified on the basis of a rigorous and codified economic analysis that assures the project benefits exceed project costs. The most rational means for selecting the project design life is on the basis of economics (i.e. project costs and cost effectiveness). This approach was used for the design of the Poplar Island Navigation Project dikes (GBA-M&N JV, 1995).

5.3.3 Dike Design Values

The dikes must be designed for a given level of hydrodynamic design conditions including winds, waves, water levels, and currents. Design conditions can be stipulated in terms of levels of risk and/or in terms of statistical return period. These two factors are related to one another and the project life through the following formula:

$$R = 1 - 1\ [1 - (1/RP)]^{L}$$

where, R=risk or probability that a given condition will be equaled or exceeded, L=project life in years, and RP=return period in years.

The normal USACE criteria stipulates that project should be designed for an event that has a 50% risk during a 50 year project life. Manipulation of the above formula will show that the normal USACE criteria corresponds to a return period of 73 years. Stated simply, the return period is the average time intervals between events of a similar magnitude. For example, a 73-year design wave would be a wave which occurs an average of once every 73 years. For this project, the design life, risk and return periods have been selected on the basis of economic optimization studies.

5.3.4 Geotechnical Factors

The main geotechnical factors that should be evaluated in the design of the containment dikes are (Pilarczk, 1990):

- Macro-instability of slopes due to failure along circular or straight sliding surfaces
- Settlements and horizontal deformations due to the self weight of the structure
- Micro-instability of slopes caused by groundwater seepage out of the slope face
- Piping or internal erosion due to seepage flow underneath the structure
- Liquefaction caused by erosion (flow down the side slopes) or by cyclic loading wave actions or earthquakes
- Erosion of revetments at the outer slopes (or underwater slopes) due to instable filters or local failure of top layer elements

The phenomena most germane to the overall planning of the dike designs are: (1) slope stability which dictates maximum allowable combinations of side slopes and structure heights and (2) settlement which influences the initial and final crest elevation of the dike. The geotechnical assessment indicates that an outer structure slope of 3H:1V is feasible (a foundation berm of sand material is required at four of the five sites). Wave runup, overtopping, armor stone sizing and toe scour protection are evaluated for a 3H:1V side slope. It is noted that this side slope is the same as that used for the majority of the dike at HMI and design for Poplar Island.

5.3.5 Dike Height - Wave Runup and Overtopping

One of the primary functions of the containment dikes is to protect the dredged material placement area against the adverse effects of high water and waves. If a high level of protection is required, the structure should have a height well above the maximum level of wave runup during storm surges. Typically, this requires setting high crest elevations for the structure. However, if some overtopping is allowed based on the nature of the facility, the design requirement can be evaluated in terms of allowable overtopping.

The level of protection against high water and wave attack has been defined as the return period of the storm event that balances initial dike construction capital costs with long-term operations and maintenance costs needed to repair the dike as a result of destruction from wave runup and/or overtopping waves. Wave runup, and more importantly, overtopping computations allow an objective means for evaluating the level of protection (i.e. allowable overtopping) offered by various dike height and armor protection combinations. In addition, wave overtopping computations provide a rational means for evaluating the relative risk of dike breaching and subsequent failure.

Wave runup is commonly evaluated on the basis of the composite-slope runup method outlined in the

Shore Protection Manual (USACE 1984). This approach has been critically reviewed by Federal Emergency Management Agency (FEMA) (1988) who found that the composite slope method provides a valid method for estimating the *mean* runup value in random waves but was lacking in its ability to predict *extreme* values of wave runup. The mean runup values computed using the FEMA composite-slope runup model are generally on the order of 2 to 4 ft above the still water level under extreme conditions (e.g. 50 to 100 year storms). Low or insignificant wave overtopping discharge values are normally computed on the basis of the mean wave runup values.

Dutch engineers have long appreciated the need to consider wave runup levels higher than the mean values in design applications and have generally used the 2% accedence runup value to select the heights of dunes and coastal dikes. Van der Meer (1992) formulae were used for computing the 2% runup for seawalls and dikes. These formulae are based on an extensive series of physical model tests including several full scale tests for 3H:1V slopes.

When a dike is located in shallow water, the higher waves will break before they reach the structure. In that case, the distribution of wave heights at the toe of the structure must take wave breaking into account.

While wave runup is an important overall indicator of the protection offered by coastal dikes, wave overtopping is judged to be a more objective and rationale method for estimating level of wave protection for the present work. Van der Meer (1992) formulae were used for estimating the mean wave overtopping on coastal structures subject to random waves.

Overtopping computations were used to develop required crest elevations for construction of a dike with no armor stone on the crest or back slope. The results indicate that required crest elevations are highest for the dike exposed to waves from the south southwest, and range from about 10 ft MLLW for a 5-year storm to about 21 ft MLLW for a 100-year event. Similarly, a dike exposed to waves from the east southeast range from about 5 ft MLLW for a 5-year storm to about 8 ft MLLW for a 100-year storm.

5.3.6 Armor Stone

There are a number of methodologies available for determining armor stone requirements for dike revetments subject to wave attack. The most commonly used method is based on the Hudson equation published in the Shore Protection Manual (USACE 1984).

The dikes will be located in relatively shallow water (10 ft to 12 ft at MLLW), and will be exposed to a wave spectrum characterized by both breaking and non-breaking waves. Sites 1 and 4B/4B-R have an existing depth of about 12 ft, whereas sites 2, 3/3-S, and 4A are deeper. The wave height used in the above equation depends on whether one is evaluating breaking or non-breaking waves. According to the Shore Protection Manual (USACE 1984), an H_{10} wave height, which is equal to

1.27 times the significant wave height, is used for the non-breaking wave height while the maximum depth limited wave height is used for breaking waves. In the present case, however, only the highest waves in the spectrum will break. Therefore, use of the Hudson equation for breaking waves could result in an overly-conservative estimate of required armor stone sizes. This is especially true given the latest Shore Protection Manual guidance for the breaking wave stability coefficient which is much lower than that published previous editions of the manual. To assume non-breaking waves, on the other hand, would be inappropriate because some of the waves in the spectrum will break.

Rock sizes using the new criteria for breaking waves are about 1.6 times larger than those computed using the older published criteria. A complete evaluation of armor stone requirements is presented in subsequent paragraphs. It suffices to say here, that use of the Hudson equation and the present recommendations for stability coefficients results in relatively large armor stone sizes.

The above comments regarding stability coefficients prompted an examination of armor stone requirements using procedures recently published by van der Meer (1988). Computations were made using van der Meer's equations for each exposure direction. The methodology presented by van der Meer is judged to be most applicable because it is based on random wave conditions which may include breaking and non-breaking waves. The guidance presented in the Shore Protection Manual are based on monochromatic (i.e. single sine wave) wave conditions. Furthermore, the Shore Protection Manual methodology is difficult to apply in situations where there are only a few breaking waves in the design wave spectrum. Accordingly, the van der Meer methodology will be used as the basis for preliminary dike design.

Although not presented in the Shore Protection Manual, the van der Meer approach has been incorporated into the USACE's Automated Coastal Engineering System (ACES) and has been recommended in lieu of the Hudson Equation in the latest draft of recommended revisions to the USACE's EM-1614 Design of Coastal Revetments, Seawalls and Bulkheads.

Computations indicate that required stone sizes for dike sections exposed to the south-southwest range from 2.0 tons for a 5-year return period to 7 tons for a 100 year return period. In comparison, the dike sections facing the southeastern exposure directions require armor stone ranging from 200 pounds for a 5-year return period to 2.5 tons for a 100-year return period.

The above armor stone requirements assume that the armor layer for the dike revetments will consist of two layers of placed rock. This is the normal design practice prescribed in the Shore Protection Manual and in many other coastal engineering references.

5.3.7 Scour Protection

Toe scour protection is the supplemental armoring of the bottom surface fronting a structure that prevents wave energy from scouring and undercutting it. Factors that affect the severity of toe scour include wave breaking, wave runup and rundown, wave reflection and grain size distribution of the beach or bottom materials. Toe stability is essential because failure of the toe will generally lead to failure throughout the entire structure. Toe scour is a complex process and specific design guidance has not been developed. Some general guidelines, however, have been suggested.

A berm toe apron has been selected for the project for several reasons: (1) the berm will provide greater protection to the structure from overtopping as a significant number of waves will break prior to reaching the side slope, (2) construction costs for a berm toe are generally lower than for a buried toe, (3) higher quantities of sediment can be suspended during excavation and construction of a buried toe, and (4) the construction methodology and environmental concerns associated with this project are better served by using a berm toe.

5.3.8 Underlayers and Filters

Revetments are normally constructed with an armor layer and one or more underlayers. Revetments often have two layers of armor and a thin underlayer overlying a geotextile built upon a core of sand or clay. Small particles beneath the geotextile should not be washed through the fabric and the underlayer stones should not be washed through the armor. In this case geotechnical filter rules are strongly recommended which are that the D_{50} of the armor is 2.2 to 2.3 times the D_{50} of the underlayer.

The Shore Protection Manual (1984) recommends that underlayer stone range of 1/10 to 1/15 of the armor weight. This results in a relatively large underlayer which has two advantages. First, a large underlayer permits surface interlocking with the armor. Second, a large underlayer gives a more permeable structure and therefore has an influence on the stability of the armor layer. For the dike design, the Shore Protection Manual criteria are recommended.

5.3.9 Dike Cross Sections

5.3.9.1 Relatively Firm Foundation Dikes

Dike cross sections vary primarily in accordance with wave exposure and foundation conditions. The following paragraphs present cross sections for firm and soft foundations for higher and lower exposure cross sections. The firm foundation dike cross sections pertain to Site 1 and portions of Site 4B. The soft foundation dike cross sections pertain to sites 2, 3/3-S, and 4A and a portion of site 4B/4B-R. It should be noted that a large number of dike cross sections were developed for this study and correspond to the five alternative island configurations. These representative sections provide a means for summarizing the basic features of the various dike types.

Figure 5-2 presents preliminary cross sections for Site 1. Section 1-A is for the most exposed portion of the perimeter dike for a relatively firm foundation. Section 1-B is for the least exposed portion of the dike. The basic features of the firmer foundation dikes are as follows:

- Designs are based on 35-year return period storm conditions
- Designs incorporate a 3H:1V side slope
- Dike heights are based on (1) allowable overtopping for an unarmored crest and (2) a generous allowance for settlement
- Stone sizes are computed using the van der Meer method
- Above grade toe protection is used
- Core is constructed using sand
- A crushed stone roadway having a width of 20 ft is located on the structure crest.

5.3.9.2 Relatively Soft Foundation Dikes

Figures 5-3 through 5-8 present preliminary cross sections for perimeter dikes on a soft foundation for Sites 2, 3, 3-S, 4A, 4B and 4B-R. Section A is for the most exposed portions of the dike; Section B is for the least exposed portions of the dike. The basic features of the soft foundation dikes are as follows:

- Designs are based on 35-year return period storm conditions
- Designs incorporate a 3H:1V side slope
- Dike heights are based on (1) allowable overtopping for an unarmored crest and (2) a generous allowance for settlement
- Stone sizes are computed using the van der Meer method
- Above grade toe protection is used
- Core is constructed using sand
- A crushed stone roadway having a width of 20 ft is located on the structure crest.
- The dike is founded on a large sand berm built with lifted rock dikes.

As previously stated, the dike cross sections presented in Figures 5-3 through 5-8 involve the placement of a large underwater berm. The purpose of this berm is to provide a stable foundation for the upper portion of the dike cross section overlying the weak soils which characterize Sites 2, 3 and 4A/B. In order to cost the underwater berm and the resulting dike cross section , it is critical to have an understanding of the means by which the dike would be constructed.

The initial stage of construction will involve stabilizing the initial outer toe of the berm. One of the key objectives is to place the toe in a way that minimizes "mud waves" and thereby minimizes the amount of sand placed to form the initial toe area. The method envisaged here is to first place a geotextile over a limited width and place sand over the geotextile. It would be best to place the sand hydraulically (i.e., either with a split hull barge or a pipeline dredge) so that sand gently "rains" down on the geotextile in a manner similar to that is used to cap dredged material. Hydraulic placement in relatively deep water would allow the soft sediment to be loaded slowly and would be less conducive to the formation of mud waves. As the sand is placed, the sand would sink into the underlying soft sediments until a stable sand embankment is achieved. The resulting geometry would involve a bulbous shaped fill that penetrates up to 10 ft or more into the soft sediments. An approximation of this bulbous shape is shown on the figures. Once the initial toe area has been stabilized, then small sand berm would be shaped to support the first rock dike. The purpose of using rock dikes is to contain the sand fill in lieu of pumping sand without containment which would result in much flatter slopes. Additionally, however, the rock containment structures would prevent the sand berm from eroding under the action of waves and currents.

Once the initial rock dike has been placed, an initial lift of sand would be placed against the rock dike. The inner or protected side of the dike may or may not incorporate a rock dike. The need for dikes along the inside of the berm is an economical question of least cost and requires a cost evaluation. The figures shows rock dikes at the outer toes.

Once the first lift has been completed, a second rock dike would be placed on the outer slope (and inner slope) and the next lift of sand would be placed. It should be noted that in order to provide an effective slope that is 3H:1V or flatter, it is necessary to stagger the dikes as shown in the figures insofar as the rock dikes themselves are normally placed on a 1.75H:1V slope.

The total number of rock toe dikes and sand lifts varies according to water depth. Once the total height of the foundation berm has been obtained, however, it will be necessary to place rock armor over the top of the horizontal berm in order to prevent erosion of that area.

Upon completion of the armored foundation berm, the upper dike would then be constructed in a fashion similar to that described for Poplar Island.

5.4 Tidal Currents and Hydrodynamic Numerical Modeling

Tidal currents in the upper bay are typically moderate to weak with average maximum velocity of about 2 ft per second (NOS 1996). The University of Maryland, (UMD) Center for Environmental Sciences (UM-CES 1997) conducted current velocity measurements using an Acoustic Doppler Current Profiler (ADCP). Sites 1, 2, 3, and 4A were surveyed during July 1997; each site was surveyed for one complete tidal cycle (about 13 hours).

A detailed examination of tidal currents and applications of tidal hydrodynamics in connection with hydraulic flow and sedimentation modeling have been developed for the Upper Bay sites. Results from the ADCP surveys were used to verify the numerical model. This modeling work has been done as part of the efforts to evaluate impacts of island construction on the environs of the project site. Flow modeling was conducted using the FASTTABS modeling system. The following paragraphs present a complete description of the model development, calibration/verification and interim analysis results.

5.4.1 Simulation Models

The numerical modeling systems used in this study are the US Army Corps of Engineers hydrodynamics (RMA-2), TABS-2 (Thomas and McAnally, 1985). The TABS-2 system consists of pre- and post-processor utility codes and three finite element two-dimensional depth-averaged computational programs. The finite element method provides a mean of obtaining an approximate solution to a system of governing equations by dividing the area of interest into smaller subareas called elements. Time-varying partial differential equations are transformed into finite element form and then solved in a global matrix system for the modeled area of interest. The solution is smooth across each element and continuous over the computational area. This modeling system is capable of simulating wetting and drying of marsh and intertidal area of the estuarine system. Both sand and clay transport can be modeled separately. The version used in this study is called FASTTABS which is the personal computer (PC) version of the main-frame based TABS-2.

The results presented in this prefeasibility study report are preliminary, and additional modeling work will be required using three-dimensional hydrodynamic models to further evaluate the sites.

5.4.2 Finite Element Mesh

The models described above require that the estuarial system be represented by a network of nodal points (i.e. points defined by coordinates in the horizontal plane and water depth) and elements (i.e. areas made up by connecting adjacent nodal points). Nodes can be connected to form 2-D (3 or 4 nodes) or 1-D elements (2 nodes). The resulting nodal/element network is commonly called a finite element mesh and provides a computerized representation of the estuarial geometry and bathymetry.

The two most important aspects in the laying out of a finite element mesh are: (1) determining the level of detail necessary to adequately represent the study area and (2) determining the extent or coverage of the mesh. The models described above are numerically robust and capable of simulating tidal elevations, flows, constituent transport and sedimentation over a mesh with reasonable resolution. Accordingly, the level of detail for the mesh is generally dictated by the bathymetric features of the estuary. With regard to the present study, it is necessary to provide greater detail in the vicinity of the upper bay sites.

There are several factors which guide decisions regarding the aerial extent of the mesh. First of all, it is desirable to extend the mesh to areas that are sufficiently distant from the proposed areas of change so that boundary conditions will not be affected by that change. Secondly, the outer regions of the mesh must be located along boundaries where conditions can be reasonably measured or are already available and can be adequately defined to the models. For example, it is more convenient to locate a boundary along a line crossing a relatively narrow well-defined channel then to locate a boundary across the middle of a large embayment, because flow conditions or tidal elevations and sediment concentrations are more easily defined for the crossing than in the open embayment.

The areal extent of the finite element mesh used covers a water area of about 2,000 square miles primarily consisting of the main stem of the Chesapeake Bay, Chester River, Bohemia River, Sassatras River, Gunpowder River, Middle River, Back River, Patapsco River, the Eastern Bay, the Choptank River and the Little Choptank River. The northern boundaries of the mesh are located at the Susquehanna River and Chesapeake and Delaware (C&D) Canal. The C&D Canal description is input using its current depth of 35 ft (MLLW). The southern boundary is located at Cove Point. These model boundaries correspond to locations where field data was collected as part of an effort to verify the three dimensional Chesapeake Bay physical model (Scheffner, *et al*, 1981).

Geometric information for the estuarial system was obtained from Nation Ocean Service/NOAA nautical charts. Depths with respect to mean low water were determined from Chart Nos. 12263, 12266, 12273, and 12278. Horizontal coordinates, x and y, for each corner node of an element and its corresponding water depth were digitized from the chart. The resulting mesh geometry was checked relative to the nautical charts and alterations were made as deemed necessary to: (1) improve physical representation of the estuary and (2) improve model stability in areas of large depth gradients.

Quadrilateral and triangular 2-D elements were used to represent the estuarial system. A fairly dense mesh was created in and adjacent to the five sites in order to accurately represent geometry changes. High resolution is achieved with a greater number of elements, however, this increase in resolution comes at the expense of added computational effort. Differences between the existing condition mesh and the meshes with the project are limited to the areas in the immediate vicinity of the islands.

5.4.3 Model Calibration

5.4.3.1 General

The finite element models must be calibrated and verified with field measurements in order to assure accurate representation of tidal flows within the modeled estuarial system. Upon completion of satisfactory calibration and verification, the model can then be used to evaluate the impacts of proposed changes on the system. The calibration process is a matter of adjusting model parameters so that model predictions match with field observations reasonably well.

Hydrodynamic model calibration is best achieved by means of a set of simultaneous measurements both along the model boundaries and throughout the estuarial system. Boundary conditions important to the present study include tidal elevation, flow velocities, freshwater discharge and so on. For a given set of boundary conditions, the model is calibrated to reproduce tidal elevations and tidal velocities within the estuary by choosing appropriate controlling parameters. The hydrodynamic model was calibrated against field measurements using recorded time-varying tidal elevations along the northern boundary at the C&D Canal and along the southern boundary. The field data measured during March 1978 are fairly representative of mean tide conditions.

5.4.3.2 Boundary Conditions and Field Data

The ideal boundary conditions for hydrodynamic calibration of the modeled system would include simultaneous tide and/or velocity records at the both southern and northern boundaries and freshwater influx records at significant tidal tributaries, namely the Susquehanna River, Gunpowder River, Bohemia River, Patapsco River, Chester River, Choptank River, Little Choptank River, Miles River, Tred Avon River, Wye River, Severn River and South River. System responses to these boundary conditions would be tide data recorded at gages throughout the system and measured discharges or velocities at selected cross-sections during the same time period as the boundary conditions.

Measurement locations available for calibration in this case include several tide stations and velocity range lines. As tide and velocity data were collected at different times, tidal measurements occurred at 3/28/1978 while velocity data were taken at 3/30/1978, it was necessary to extrapolate tide data from 3/28/1978 to 3/30/1978 for calibration purposes. Average freshwater flow data were available for the Susquehanna River, Patapsco River, Chester River, Bohemia River, Gunpowder River, Choptank River, Wye River and Severn River. Average discharges for other rivers were estimated based on the drainage areas. It was found that the fresh water discharges play a secondary role compared with tidal elevations and velocities.

In general, wind tends to modify bay water surface elevations through wind-induced set-up. Wind-induced currents, on the other hand, are normally much weaker than the tidal currents, depending on wind speed. For example, a typical wind speed of 11 mph from the south was imposed on the model in order to examine the effect on both elevation and velocity. Model results indicated little difference between the with- and without- wind condition. It was judged, therefore, that the wind effect was not critical for model calibration. It should be noted however, that wind can be an important factor for sediment transport and was incorporated into sedimentation modeling.

5.4.3.3 Model Parameters

Different combinations of parameters were tested in the calibration process. The most important calibration parameters are eddy viscosity and Manning's n which effect lateral mixing and bottom friction of the flow system, respectively. A final set of eddy viscosity and Manning's n values were chosen for different areas within the system in terms of water depth to provide the best fit of measured and simulated water elevations and flows at the various locations within the estuarial system. Table 5-4 gives the calibrated values of eddy viscosity and Manning's n.

5.4.3.4 Calibration Results

The hydrodynamic model was operated for the existing condition with a half-hour time-step over a 72-hour period. The simulation period was found to be long enough to eliminate the transient effects associated with initial conditions.

Calibration results show that the agreement between the simulated and recorded tides is good in terms of both amplitude and phase, and the simulated velocities are in reasonable agreement with field measurements. Accordingly, it is judged that the model simulations conducted for the present study are fairly consistent with the field measurements.

5.4.4 Model Verification

Model verification is a necessary next step after model calibration to further validate the hydrodynamic model. The purpose of model verification is to prove that the previously calibrated model parameters, namely eddy viscosity and Manning's n, are still valid for a different set of field data.

The measured tidal elevation and velocity data in Fall 1983 and data collected in July 1997 by UMD (UM-CES 1997) were used for verification purposes.

Based on the model calibration and verification results, it is concluded that the finite element model constitutes a reasonable representation of tidal hydrodynamics throughout the modeled estuarial system. Figures 5-9 and 5-10 present peak flood and peak ebb velocity vectors for existing conditions.

5.4.5 Impacts Of Island Construction

The calibrated and verified model was used to evaluate the impacts of island construction on tidal hydrodynamics residence times, salinity, concentration decay of discharge from HMI and sedimentation in the upper bay estuarial system under the normal tide conditions. Boundary conditions used for calibration purposes were also used for project conditions.

5.4.5.1 Hydrodynamics

Site 1 Changes from existing conditions are as would be expected. Specifically, the presence of the island has several impacts. First, the waters presently flowing through are forced to travel around the island. This tendency increases flow on the exterior edges of the island. During flood flow, water that passes through Site 1 under existing conditions will split in the vicinity of the southernmost point of the proposed dike alignment. After construction, this split flow is then trained along the western and eastern shorelines of the island. The increases in flow velocities relative to existing conditions are on the order of 0.1 to 0.3 ft per second. During ebb flow, water movement splits at the northern end of the island and is trained along the western dike and the eastern shorelines. Ebb flows fronting the dike are also increased about 0.1 to 0.3 ft per second relative to existing conditions.

Site 2 Changes from existing conditions are as would be expected as the waters presently flowing through are forced to travel around the island. This tendency increases flow on the exterior edges of the island and especially in the shipping channels. During ebb flow, water movement splits at the northern end of the restored island and is trained along the western and eastern shorelines of the island. Flood and ebb flows fronting the dike are increased about 0.1 to 0.6 ft per second relative to existing conditions.

Site 3 Changes from existing conditions are as would be expected, as waters presently flowing through are forced to travel around the island. This tendency increases flow on the exterior edges of the island. During flood flow, water that passes through Site 3 under existing conditions will split in the vicinity of the southernmost point of the proposed dike alignment. After construction, this split flow is then trained along the western and eastern shorelines of the island. The increases in flow velocities relative to existing conditions are on the order of 0.1 to 0.5 ft per second. During ebb flow, water movement splits at the northern end of the island and is trained along the western dike and the eastern shorelines. Ebb flows fronting the dike are increased about 0.1 to 0.5 ft per second relative to existing conditions.

Site 3-S Changes from existing conditions are not as great as that for Site 3 as water would still flow over the submerged containment island. The increases in flow velocities relative to existing conditions for flood and ebb flow are on the order of 0.1 to 0.4 ft per second.

Site 4A Changes from existing conditions are significant as the waters presently flowing through are forced to travel through the narrowed gap between the island and the eastern shore.
The increases in flow velocities relative to existing conditions are on the order of 0.1 to 0.7 ft per second for both flood and ebb flow.

Site 4B Changes from existing conditions are not as dramatic as for Site 4A. Increase in flow is primarily on the eastern exterior edges of the island. The increases in flow velocities relative to existing conditions are on the order of 0.1 to 0.3 ft per second for both flood and ebb.

Site 4B-R Changes from existing conditions are similar to 4B and also are not as dramatic as for Site 4A. Increase in flow is primarily on the eastern exterior edges of the island.

The increases in flow velocities relative to existing conditions are on the order of 0.1 to 0.3 ft per second for both flood and ebb.

5.4.5.2 Residence Times, Salinity, and HMI Discharge

The hydrodynamic analysis of the preceding section was subsequently used to evaluate impacts to residence times, salinity, and effluent discharge from HMI. Impacts to these parameters are used as indicators to assess potential impacts to biologically-related processes in the upper bay. Table 5-5 presents a comparison of each site to existing conditions in order of decreasing impacts to the subject parameter. The greatest increase in residence is about one day for Sites 3, 3-S and 1, and about 0.5 days for Sites 4A, 4B, 4B-R and 2. The greatest increase in salinity above Pooles Island is about 0.5 ppt for Sites 4A, 4B-R, and 4B, and minimal change for Sites 3-S, 1 3 and 2. Very slight increases in concentration levels for dispersion of effluent from HMI occur for Sites 3, 4A, and 4B-R. Imperceptible changes occur for Sites 3-S, 1, 4B and 2.

5.4.5.3 Sedimentation

Similar to residence times, the hydrodynamic results of calibration boundary conditions from RMA-2 were used in the numerical sediment transport code STUDH as input information to solve the depth-integrated convection-diffusion equation for a single sediment constituent. Sediment transport modeling results provide an average sedimentation (erosion or accretion/deposition) approximation across each computational element. It should be noted, however, that the model does not compute a new flow field due to the change in bathymetry resulting from sediment transport. Model simulations were run for relatively short durations, therefore, to minimize the effect of a change in flow patterns.. Sedimentation was modeled for a three-day duration for each of the eight cases.

Table 5-1
Astronomical Tidal Datum Characteristics for Upper Chesapeake Bay Locations
(ft, MLLW)

Tidal Datum	Pooles Island	Tolchester	North Point	Seven Foot Knoll	Cove Point
Mean Higher High Water (MHHW)	1.8	1.7	1.4	1.3	1.7
Mean High Water (MHW)	1.5	1.4	1.3	1.1	1.4
Mean Tide Level (MTL)	0.9	0.8	0.8	0.6	0.6
National Geodetic Vertical Datum (NGVD)	0.3	0.3	0.3	0.3	0.3
Mean Low Water (MLW)	0.3	0.2	0.2	0.2	0.2
Mean Lower Low Water (MLLW)	0.0	0.0	0.0	0.0	0.0

Table 5-2
Annual Extreme Wind Speed Per Direction
for Baltimore-Washington International (BWI) Airport, 1951-1982
Fastest Mile Wind Speed (MPH)

Year	North	Northeast	East	Southeast	South	Southwest	West	Northwest	All Directions
1951	24	41	27	34	39	29	42	46	46
1952	66	25	47	66	41	66	46	43	66
1953	20	28	22	27	34	39	47	43	47
1954	31	27	22	60	28	39	57	44	60
1955	21	43	29	28	43	53	40	43	53
1956	29	34	25	24	28	34	56	40	56
1957	29	53	35	33	33	30	46	46	53
1958	30	52	25	33	37	43	40	43	52
1959	28	26	20	27	23	38	46	43	46
1960	26	38	28	27	25	35	40	53	53
1961	45	28	28	29	24	70	41	54	70
1962	56	41	28	17	25	36	42	61	61
1963	38	32	18	34	25	28	44	60	60
1964	34	31	23	24	47	23	48	61	61
1965	36	26	28	34	36	54	44	44	54
1966	32	25	29	24	47	43	50	48	50
1967	30	29	25	39	27	46	53	43	53
1968	45	30	36	26	19	45	48	50	50
1969	28	21	20	34	26	45	45	53	53
1970	28	28	18	21	39	34	48	60	60
1971	31	45	26	18	21	41	39	58	58
1972	28	25	35	26	20	41	41	41	41
1973	40	26	26	38	26	35	49	33	49
1974	32	23	46	29	33	33	45	41	46
1975	40	26	21	24	25	38	54	45	54
1976	31	18	20	28	32	28	45	54	54
1977	32	31	19	28	26	25	49	48	49
1978	39	28	36	28	19	52	33	45	52
1979	32	25	27	36	32	32	45	47	47
1980	33	27	18	32	20	32	45	50	50
1981	24	24	19	26	23	28	41	42	42
1982	31	20	23	23	29	34	40	48	48

Note: Data adjusted to 10 meter height.

Table 5-3

Design Wind speeds per Direction and Return Period (mph)

Return Period	Direction								
	N	NE	E	SE	S	SSW	SW	W	NW
5	40	37	32	37	36	42	47	50	54
10	48	44	38	45	43	50	56	54	59
15	52	48	41	50	47	54	61	56	62
20	56	52	45	55	51	59	67	59	65
25	59	55	47	58	54	62	70	60	67
30	62	57	49	61	56	65	73	61	68
35	64	60	51	63	58	67	76	62	70
40	66	62	53	65	60	69	78	63	71
50	69	66	55	69	63	73	82	64	73
100	81	76	65	82	74	86	97	69	81

Table 5-4
Hydrodynamic Parameters

Water Depth (ft)	Eddy Viscosity (lb-sec/ft^2)	Manning's n (sec/ft$^{1/3}$)
<10	350	0.030
10 to 70	300	0.025
>70	250	0.020

Table 5-5
Impacts Compared to Existing Conditions in Order of Decreasing Impact

Residence Time	Salinity	Concentration
3	4A	3
3S	4B-R	4A
1	4B	4B-R
4B-R	3S	3S
4B	1	1
4A	3	4B
2	2	2

Table 5-6
Cohesive Sedimentation Parameters

Model Parameters	Units	Values
Crank-Nicholson THETA	none	0.66
critical shear stress (deposition)	N/m^2	0.05
critical shear stress (erosion)	N/m^2	0.15
dry density of freshly deposited material	kg/m^3	300
particle specific gravity	none	2.65
erosion rate constant	$kg/m^2/sec$	0.002
effective diffusion	m^2/sec	50
inflow concentration	kg/m^3	0.02
settling velocity	m/sec	0.0003
initial concentration	kg/m^3	0.02

Table 5-7
Noncohesive Sedimentation Parameters

Model Parameters	Units	Values
Crank-Nicholson THETA	none	0.66
particle shape factor	none	0.70
length factor (deposition)	none	0.50
length factor (erosion)	none	10
particle specific gravity	none	2.65
median grain size	mm	0.2
effective diffusion	m^2/sec	50
inflow concentration	kg/m^3	0.001
settling velocity	m/sec	0.005
Manning's n	none	0.025

Table 5-8
Impacts Compared to Existing Conditions
In Order of Decreasing Impact

Cohesive w/o Wind	Cohesive with Wind	Non-Cohesive w/o Wind	Non-Cohesive with Wind
4A	4A	4A	4A
4B	3S	4B	3S
2	2	2	1
3S	3	3S	2
1	4B	3	3
3	1	1	4B
4B-R	4B-R	4B-R	4B-R

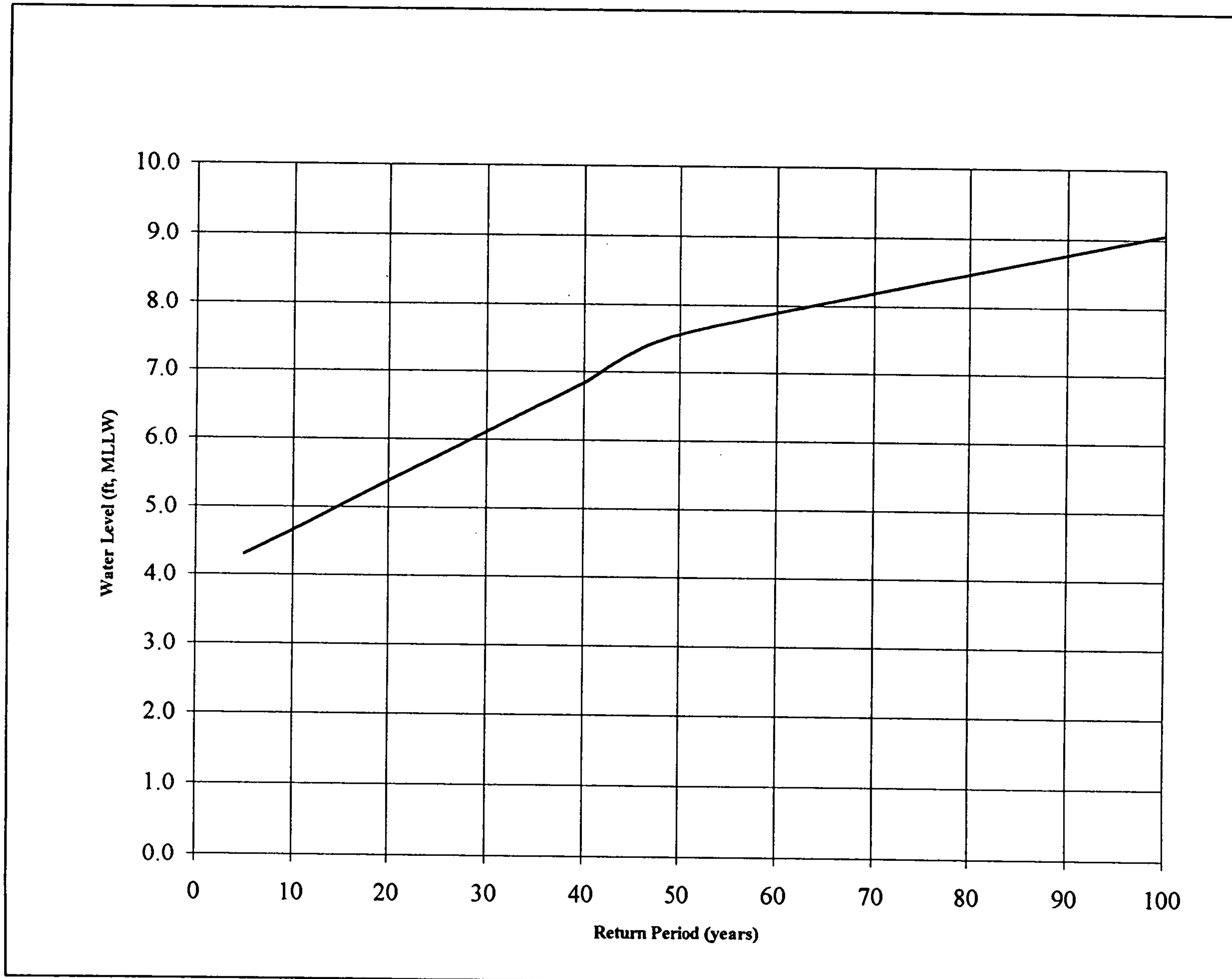


Figure 5-1. Design Water Levels (ft, MLLW) for the Five Site Study Areas.

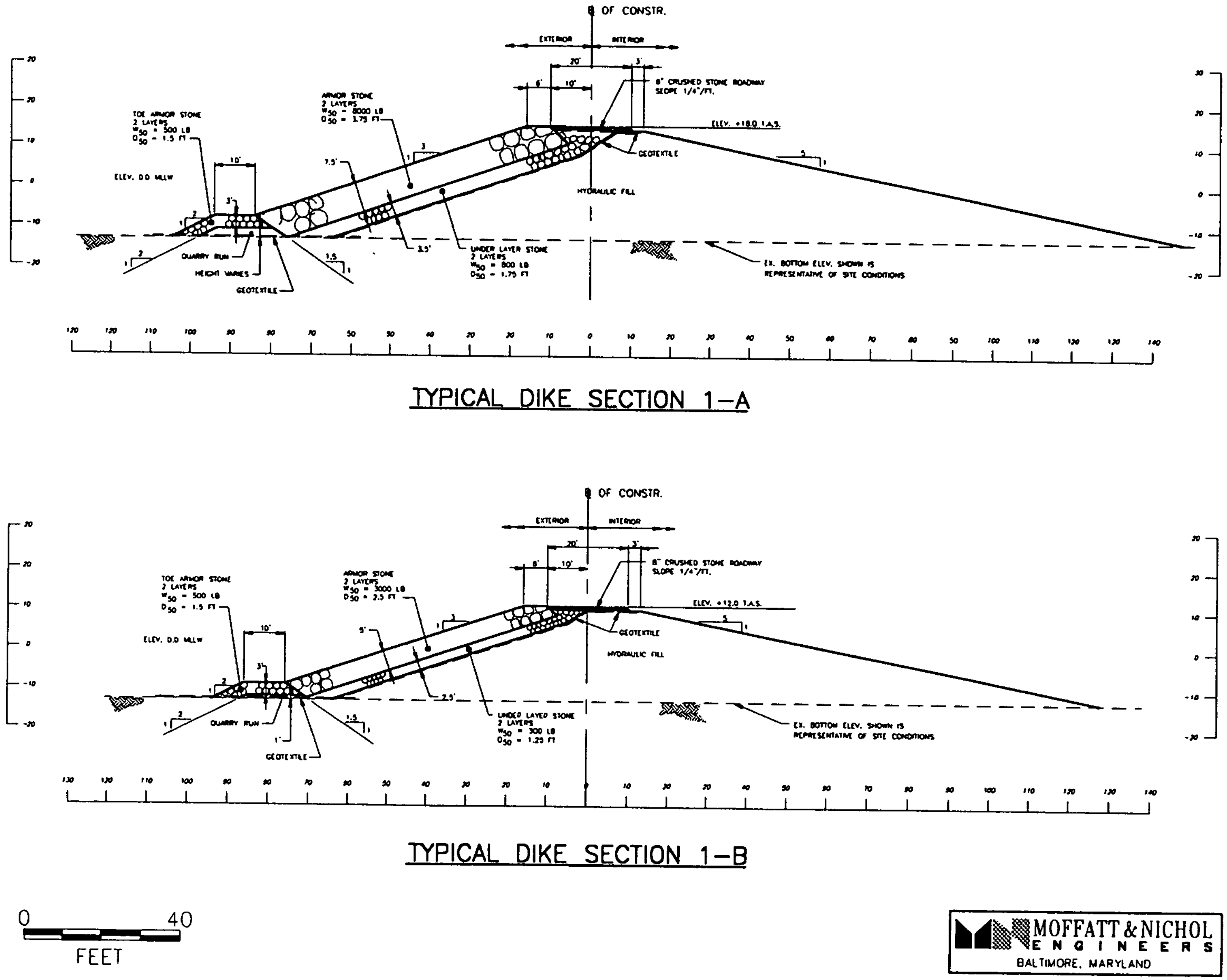


Figure 5-2. Typical Dike Sections 1-A and 1-B.

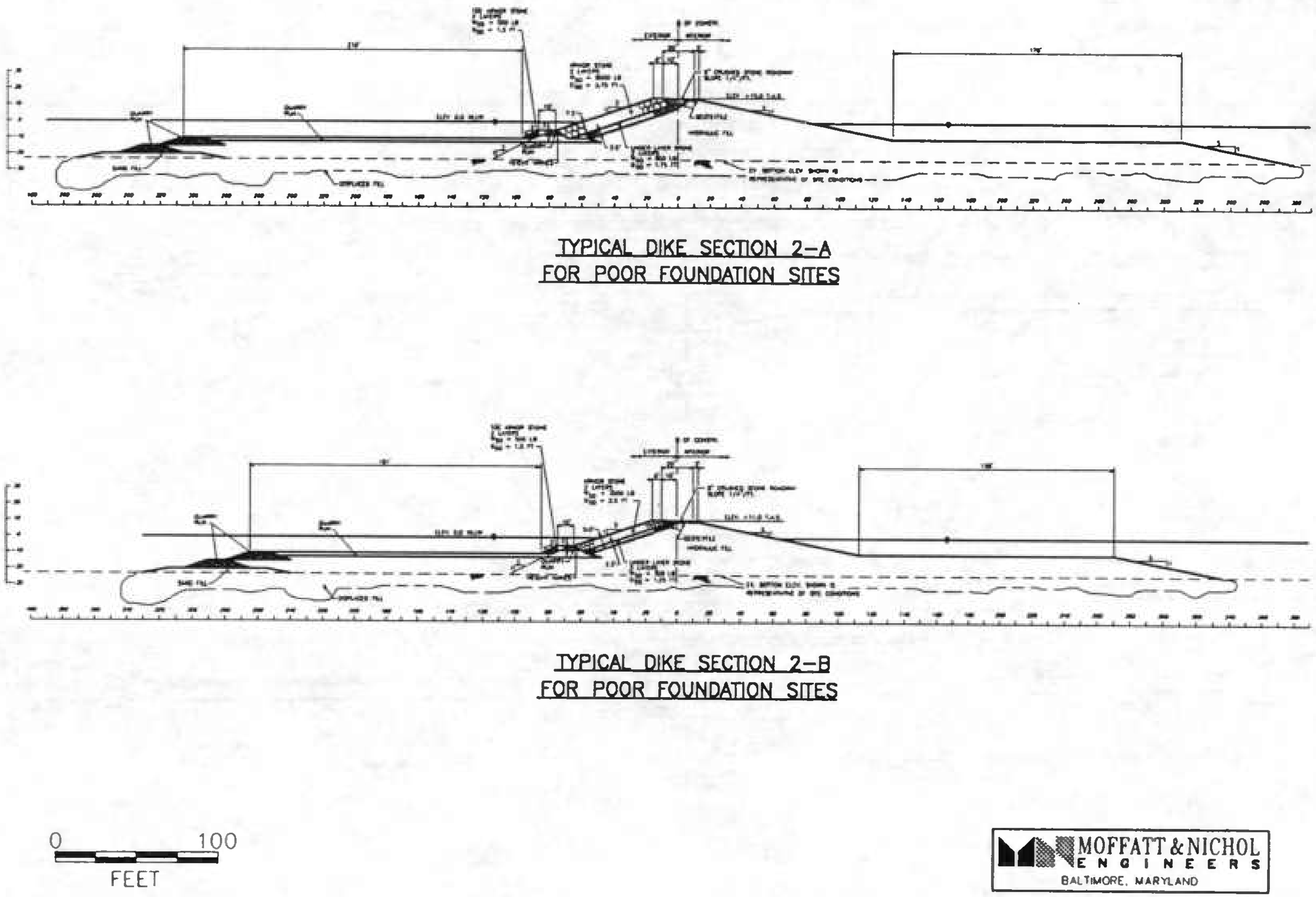
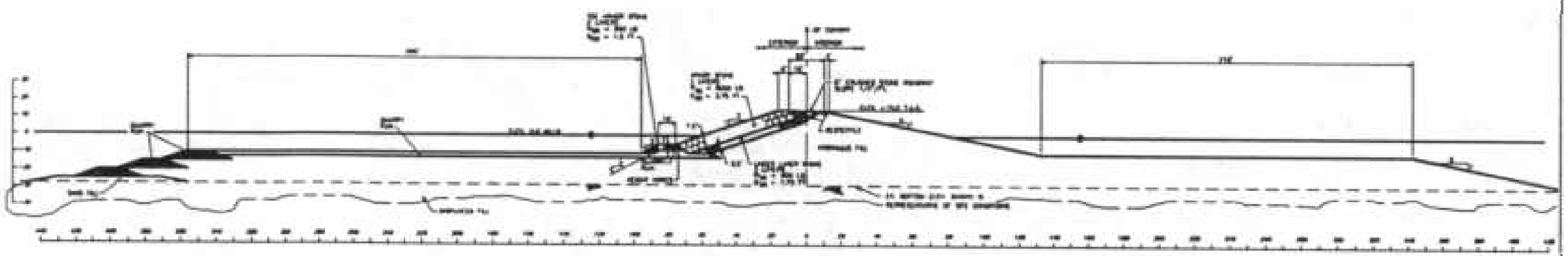
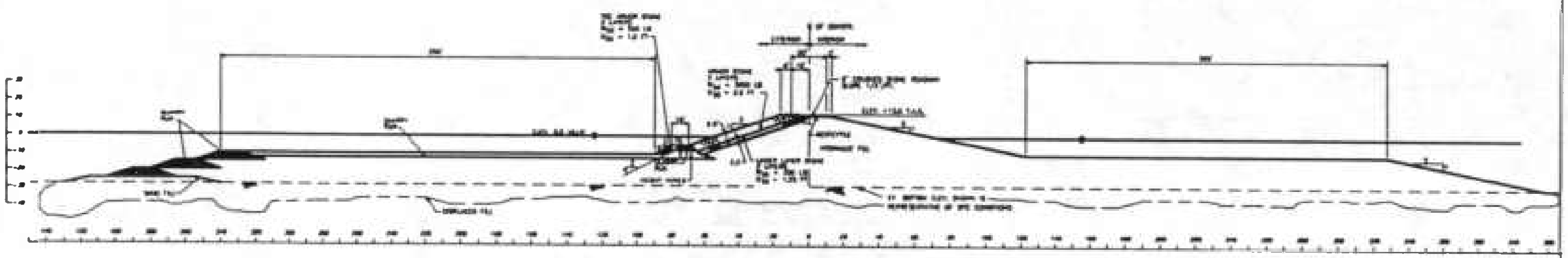


Figure 5-3. Typical Dike Sections 2-A and 2-B.



TYPICAL DIKE SECTION 3–A
FOR POOR FOUNDATION SITES



TYPICAL DIKE SECTION 3–B
FOR POOR FOUNDATION SITES

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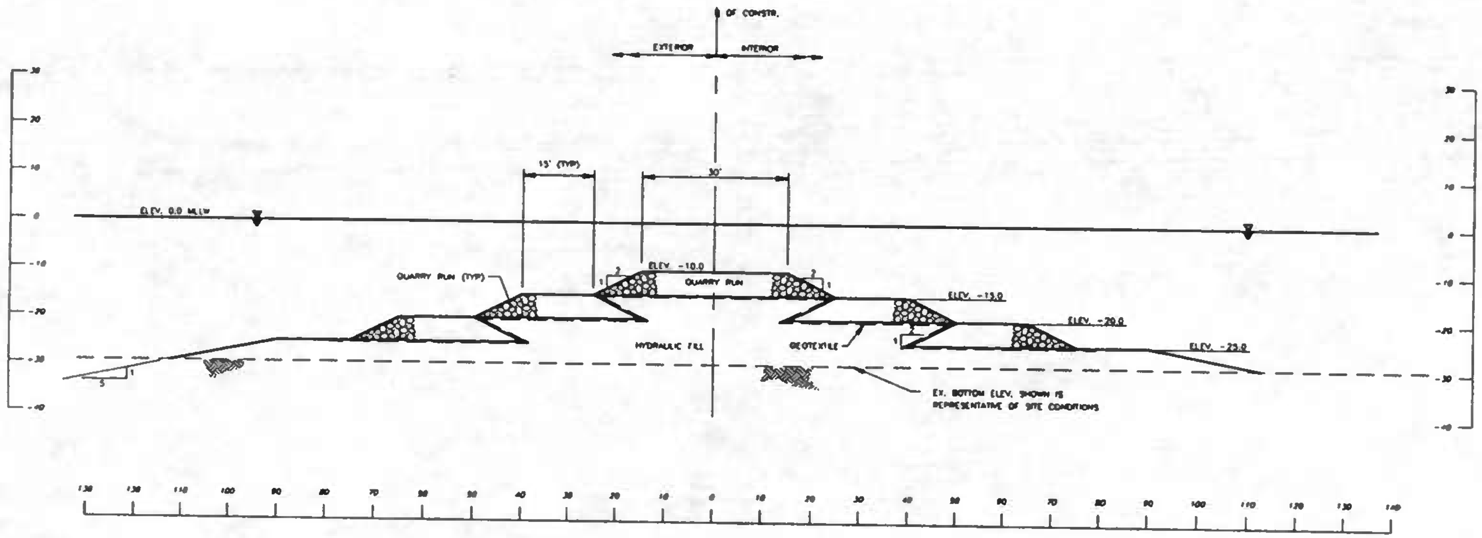
Figure 5–4. Typical Dike Sections 3–A and 3–B.



TYPICAL DIKE SECTION 3-S

0 40
FEET

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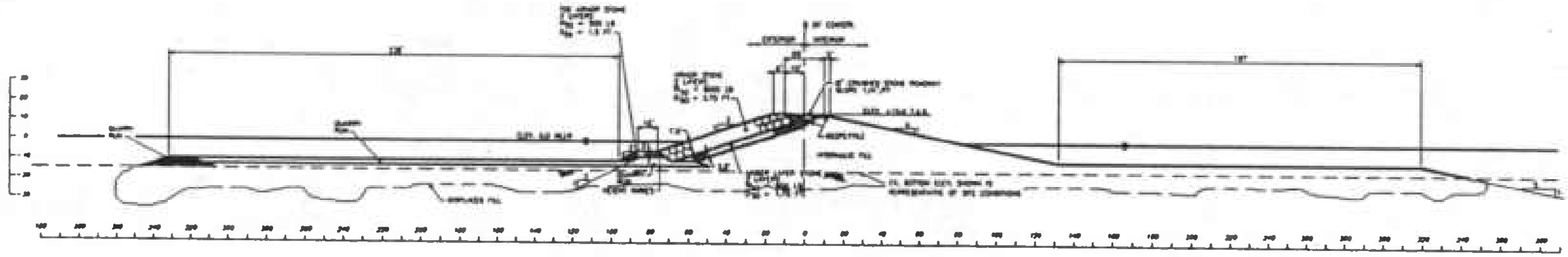
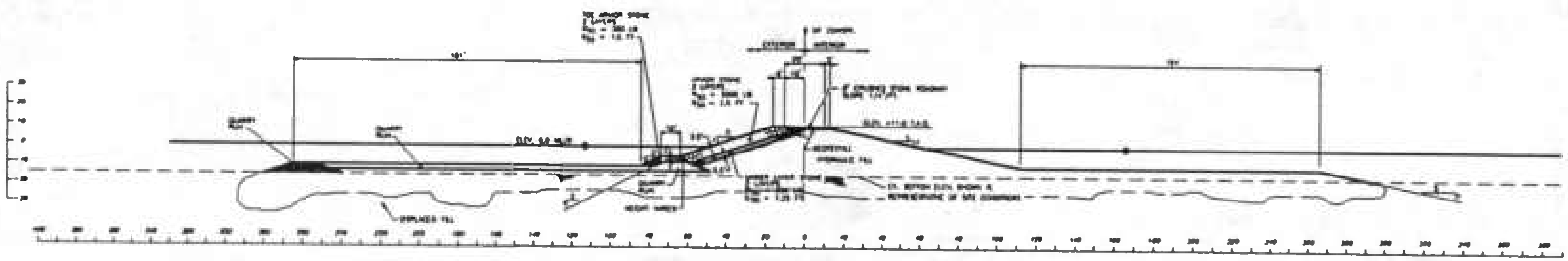
Figure 5-5. Typical Dike Section 3-S.



TYPICAL DIKE SECTION 4A–A
FOR POOR FOUNDATION SITES



TYPICAL DIKE SECTION 4A–B
FOR POOR FOUNDATION SITES

0 100
FEET

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Figure 5–6. Typical Dike Sections 4A–A and 4A–B.

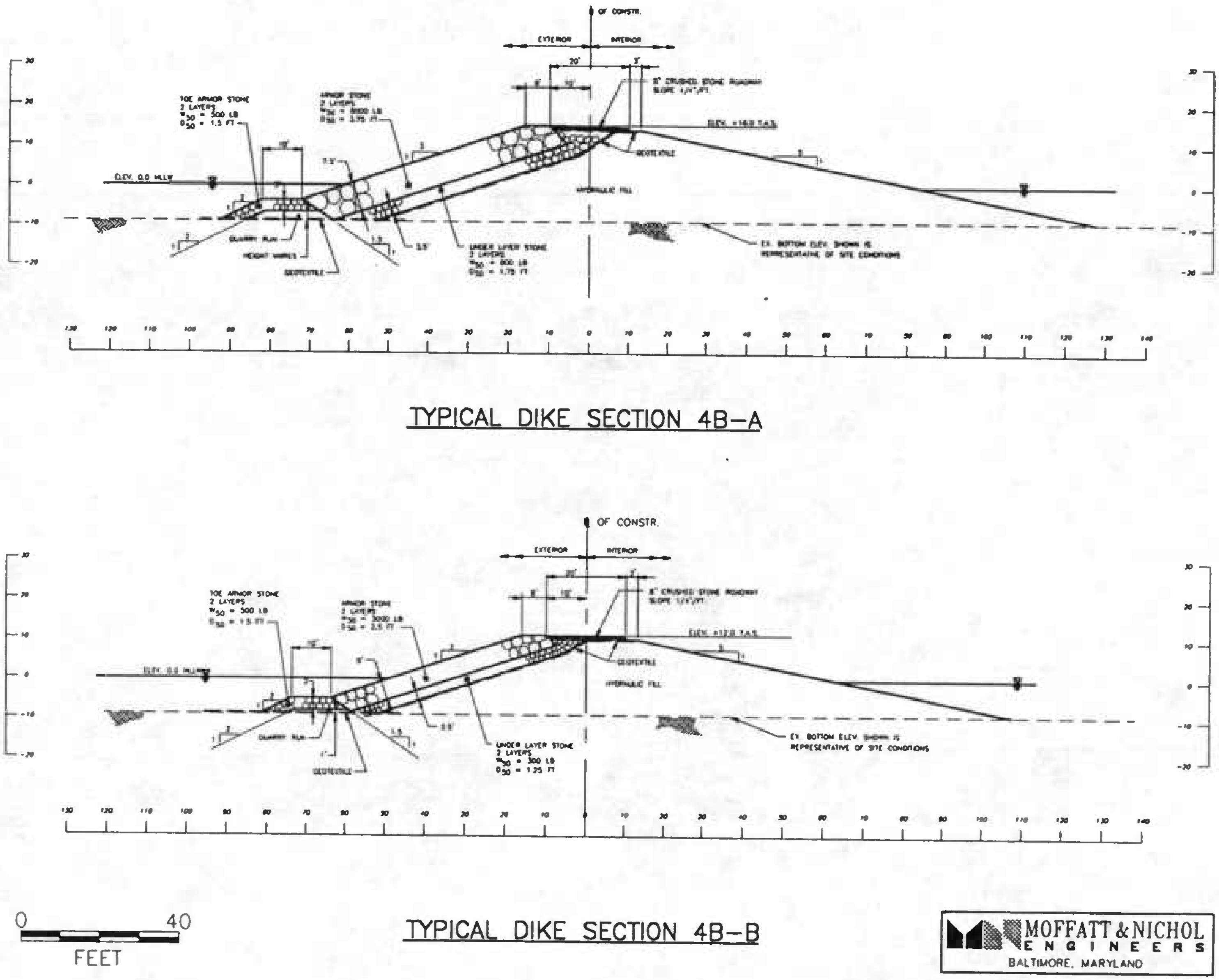
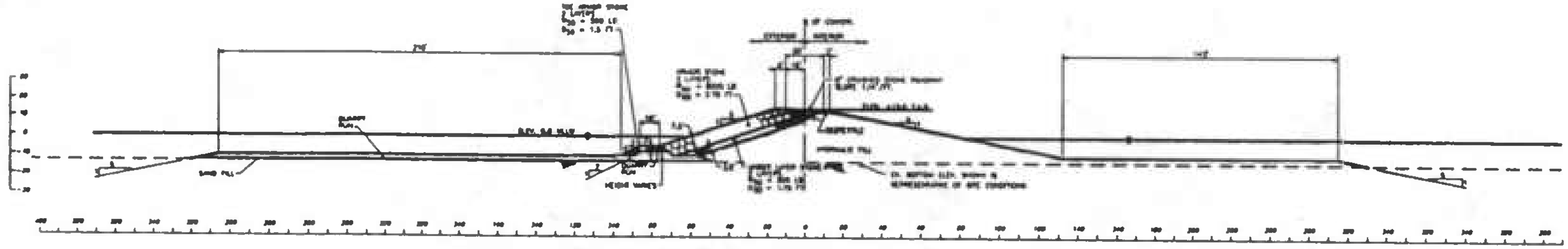
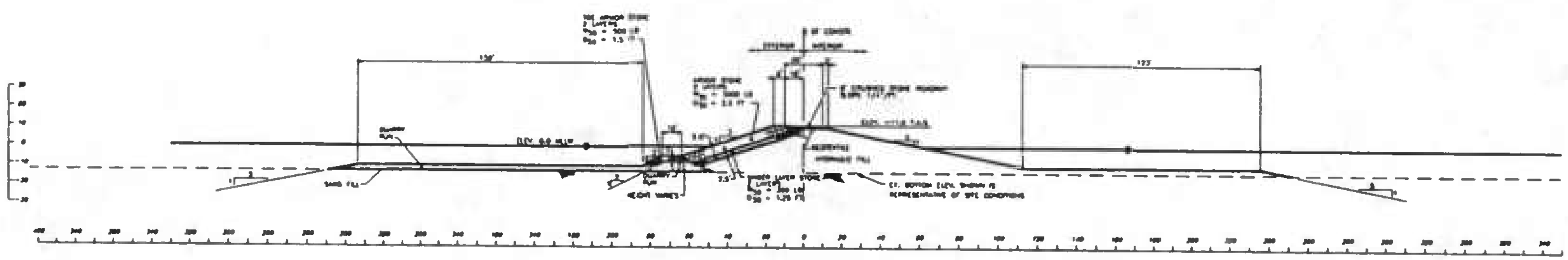


Figure 5-7. Typical Dike Sections 4B-A and 4B-B.



TYPICAL DIKE SECTION 4B-R-A
FOR POOR FOUNDATION SITES



TYPICAL DIKE SECTION 4B-R-B
FOR POOR FOUNDATION SITES

0 100
FEET

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Figure 5-8. Typical Dike Sections 4B-R-A and 4B-R-B.

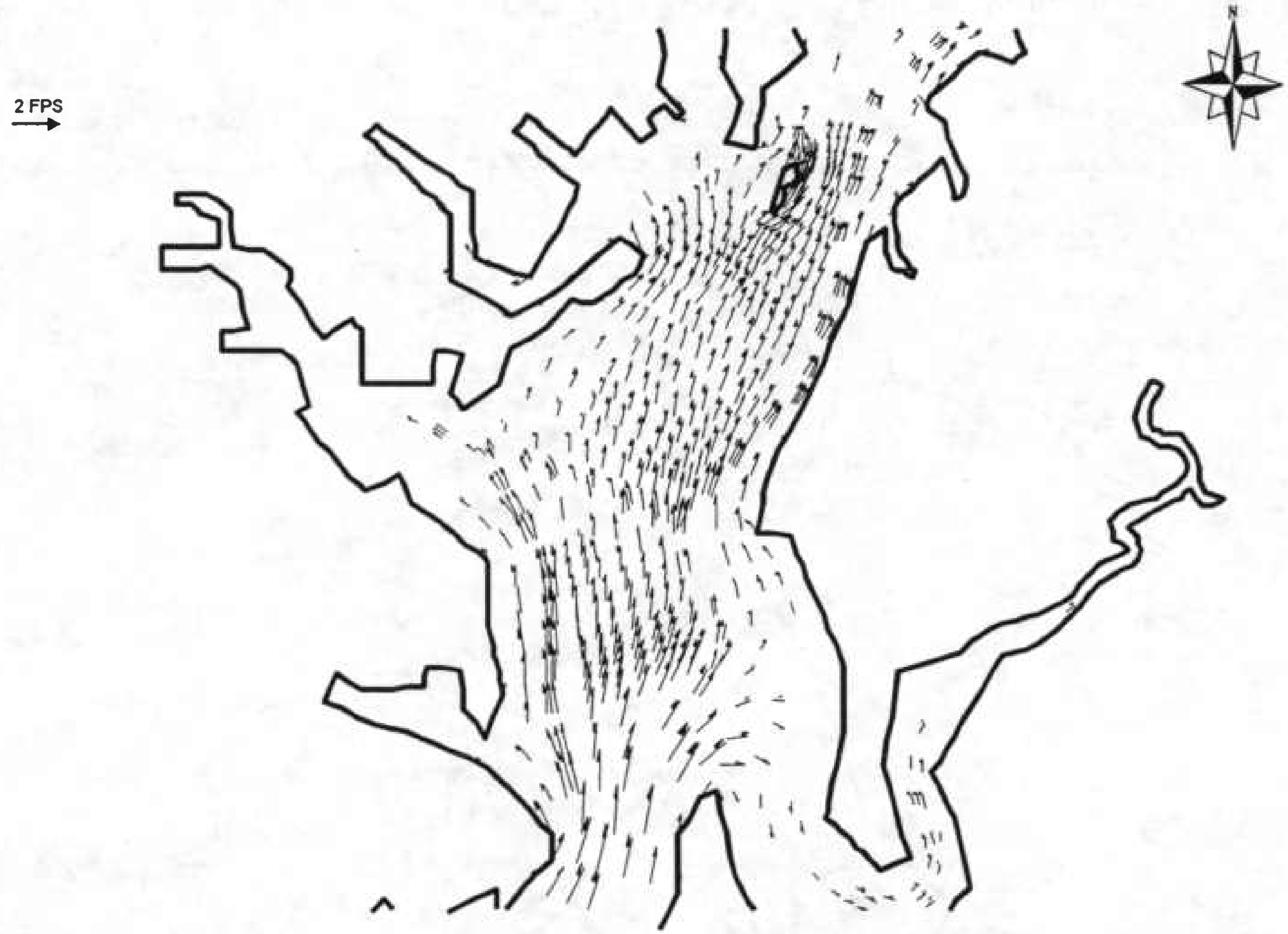

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Figure 5-9. Peak Flood Velocity Vectors Existing Conditions.

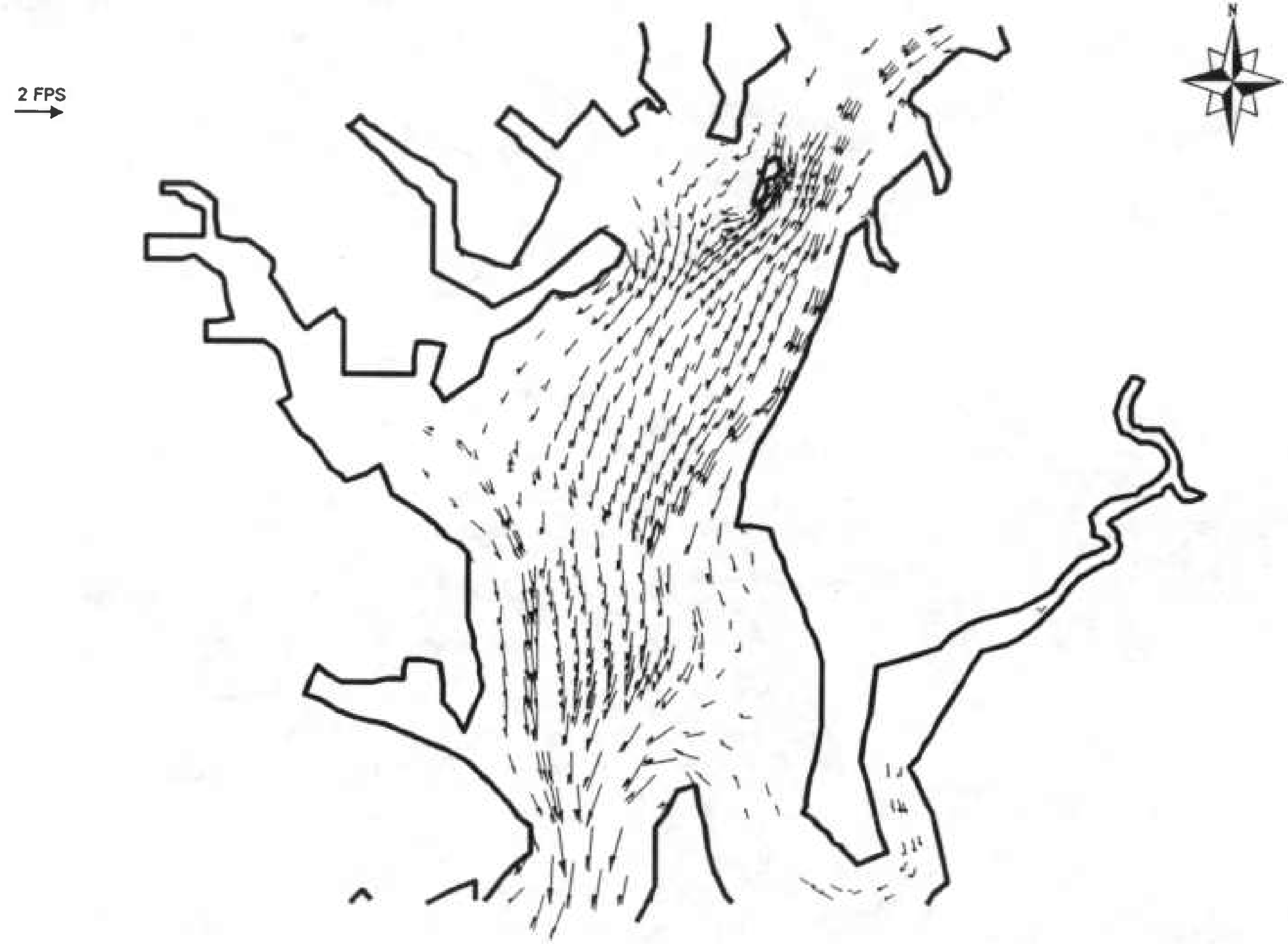

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Figure 5-10. Peak Ebb Velocity Vectors Existing Conditions.

6.0 DREDGING & SITE ENGINEERING INVESTIGATION

The dredging and site engineering investigation concentrated on site layouts, site conceptual designs, site construction and operation, site costs, and comparison of alternatives from a cost perspective.

6.1 Site Layouts

Site layouts were generated by giving due consideration of the following factors:

- *Geographical Considerations:* This includes the desired distance of the site from the dredging area's and preferred geometry of the site. A transport distance of 25 nm was taken as the maximum in order to minimize transportation cost. A near-circular or elliptical shape yields largest surface area per unit length of the dikes and was therefore preferred.

- *Physical Considerations:* This includes water depth at the site, tidal range, wave characteristics, magnitude of storm surges, and velocity and direction of currents. Deeper water depths yield larger site capacity and higher dike construction costs, while shallow water depths will restrict barge access during construction and material placement. Therefore, a balance was considered optimal. The sites were aligned in such a way that minimal hydrodynamic impacts would result from their construction.

- *Biological Considerations:* This includes assessment of potential impacts of island construction on benthos, fish, and other sensitive species. Considerations included total abundance, species diversity, relative productivity, and the aerial extent of SAV. Island footprints were selected to minimize potential biological impacts.

- *Environmental Considerations:* This includes evaluation of potential impacts on water quality, presence of contaminants at the site, and previously impacted areas (historical dredged material or industrial waste discharge areas). Site layouts were selected so that there will be minimal impacts to the biota and fisheries/oyster resources and minimal potential resuspension of sediment-bound contaminants into the water column.

- *Geotechnical Considerations:* This includes consolidation, permeability, and shear strength of the foundation material which dictates to a large extent the dike design at the site and the site capacity. While softer sediments provide added site capacity resulting from settlement, they also cause concerns regarding the integrity of the dike. Therefore, a firm, strong foundation (such as sands) may be preferred over soft, fine-grained sediments. In addition, sandy sediments could provide additional site capacity if the sandy sediments within the footprint are used for dike construction.

- *Other Considerations:* This includes cultural/archeological resources, aesthetics, jurisdiction issues, and other factors. Considerations include evaluation (mapping/surveys) of historical and archeological value of the site, avoidance of underwater pipeline routes and military exclusion zones, aesthetics (visual and shoreline impacts), and federal/state/local jurisdictional issues (regulations, enforcement, and political boundaries).

Based on dredging and site engineering aspects, and coastal, environmental and geotechnical factors, preliminary site alignments were developed for planning purposes. A range of site areas (500 to 2000 acres) were initially investigated in order to develop a relationship between site areas, dike heights, site capacity and operational life for the four study sites. As the prefeasibility study progressed, MPA directed the consultants to narrow the study options for an operational life of 20 years for the site. Two dike heights were subsequently considered for each site: (i) an initial dike elevation during site construction (as permitted by the foundation strength and dike stability considerations), and (ii) a maximum permissible dike elevation for future dike raising, which considers increase in foundation strength due to long-term consolidation. For Site 4-B, an additional site alignment (4B-R) was also considered due to the environmental sensitivity of the northern portion of the site. Final site layouts were determined based on discussion between MPA and the consultants, considering all of the above mentioned factors for site layout.

6.1.1 Site 1

A bearing of 200° was chosen as the optimal value for the major axis for Site 1 based on the results of the coastal engineering and hydrodynamic analysis by M&N (1997). Two site alignments were developed at this site based on a target site life of 20 years: (i) Alignment 1-1, which has a surface area of 1,060 acres, and a dike elevation of 25 ft, and (ii) Alignment 1-2, which has a surface area of 790 acres, and a dike elevation of 35 ft. The site alignments were chosen based on the best available geotechnical information, and in consideration of foundation characteristics and suitable borrow material for dike construction. Details of the layouts can be obtained from Plate Nos. A-1 and A-3.

6.1.2 Site 2

A bearing of 220° was chosen as the optimal value for the major axis for Site 2 based on the results of the coastal engineering and hydrodynamic analysis by M&N (1997). The bearing was also selected based on the alignment of the adjacent Tolchester Channel. Two site alignments were developed at this site based on a target site life of 20 years: (i) Alignment 2-1, which has a surface area of 1,195 acres, and a dike elevation of 15 ft, and (ii) Alignment 2-2, which has a surface area of 1,075 acres, and a dike elevation of 18 ft. The site alignments were chosen based on the best available geotechnical information, which at this site appears to be homogeneous throughout the area, and therefore did not influence the alignment considerably. Details of the layouts for Site 2 can be obtained from Plate Nos. A-1 and A-4.

An alternate location for Site 2 was also identified along the northwest boundary of the site with a bearing of 200° (see Plate A-4). This location was identified based on the potential for better quality foundation materials at that location, determined from limited geotechnical borings. Additional geotechnical investigations would be required before the site can be shifted to this location.

6.1.3 Sites 3 and 3-S

A bearing of 200° was chosen as the optimal value for the major axis for Site 3 based on the results of the coastal engineering and hydrodynamic analysis by M&N (1997). Two options were considered for Site 3: (i) an island option, and (ii) a subaqueous option, considering the deep water depths available at the site. Two site alignments were developed for the island option at this site based on a target site life of 20 years: (i) Alignment 3-1, which has a surface area of 1,065, and a dike elevation of 15 ft, and (ii) Alignment 3-2, which has a surface area of 975 acres and a dike elevation of 18 ft.

For the subaqueous option, only one alignment could satisfy the 20 year life requirement: Alternative 3-S, with a surface area of 3,000 acres, and a dike elevation of -10 ft. The site alignments were chosen based on water depth and the best available geotechnical information, which at this site appears to be homogeneous throughout the area, and therefore did not influence the alignment considerably. Details of the layouts for Sites 3 and 3-S can be obtained from Plate Nos. A-1 and A-5.

6.1.4 Site 4A

A bearing of 200° was chosen as the optimal value for the major axis for Site 4A based on the results of the coastal engineering and hydrodynamic analysis by M&N (1997). Two site alignments were developed at this site based on a target site life of 20 years: (i) Alignment 4A-1, which has a surface area of 1,475 acres, and a dike elevation of 15 ft, and (ii) Alignment 4A-2, which has a surface area of 1,300 acres, and a dike elevation of 18 ft. The site alignments were chosen based on the results of hydrodynamic modeling and the best available geotechnical information. Details of the layouts for Site 4A can be obtained from Plate Nos. A-1 and A-6.

6.1.5 Sites 4B and 4B-R

A bearing of 200° was chosen as the optimal value for the major axis for Site 4B based on the results of the coastal engineering and hydrodynamic analysis by M&N (1997). Two options were considered for Site 4B due to the sensitive nature of the northern portion of the site: (i) an option which connects to the Pooles Island to yield a 20-year operational life (4B), and (ii) an option that is located to the south of Pooles Island which will yield only a 10-year operational life (4B-R). Two site alignments were developed for 4B based on a target site life of 20 years: (i) Alignment 4B-1, which has a surface area of 1,125 acres, and a dike elevation of 25 ft, and (ii) Alignment 4B-2, which has a surface area of 825 acres, and a dike elevation of 35 ft. Note that the dike heights for 4B-1 and 4B-2 represent average values over the site, due to the wide variability of soil conditions at the site.

For 4B-R, only a 10-year life was possible, and therefore two alignments were developed as follows: (i) Alignment 4B-R-1, which has a surface area of 780 acres, and a dike elevation of 15 ft, and (ii) Alignment 4B-R-2, which has a surface area of 680 acres, and a dike elevation of 18 ft. The site alignments were chosen based on the results of hydrodynamic modeling and the best available geotechnical information, and in consideration of foundation characteristics and suitable borrow material for dike construction. Details of the layouts for Site 4B can be obtained from Plate Nos. A-1 and A-6.

6.2 Site Conceptual Designs

Site design for the various study sites involved consideration of the following factors:

- *Site Surface Areas:* Site surface areas were selected so that they do not cause significant environmental impact and that they do not lie in extremely deep waters. For initial evaluation, a range of site areas from 500 to 2,000 acres were considered for the sites. A relationship between site area and lift thickness was developed for planning purposes (for various quantities of dredged material placed at the site), as shown in Figures 6-1 through 6-7.

- *Dike Elevations & Fill Volumes:* Dike elevations ranging from 10 to 40 ft were considered for initial evaluations. During optimization of site designs, the dike elevations were further narrowed down to an initial construction elevation, and a potential maximum elevation, based on geotechnical considerations of slope stability and gain in foundation strengths. Dike elevations and cross-sections are presented in Plate Nos. A-10 through A-15.

- *Rock Protection & Volumes:* Rock protection for the dikes was designed to yield sufficient protection against the adverse effects of high water and waves resulting from a 35-year return period storm (M&N, 1997). In order to yield a high degree of protection, the armor layer was designed to a height greater than the maximum level of wave runup during storm surges. In general, the rock sections consists of a toe protection structure, geotextile filter fabric, underlayer stones, and armor stones (see Plates A-10 through A-15).

- *Potential Borrow Sources & Volumes:* Based on data from the USACE (1981) and geotechnical investigations (E2Si, 1997), five potential borrow sources (PBS) with sand volumes ranging from approximately 267,000 cy to 24 million cy were identified. The location of these sources and volumes are summarized in Plate No. A-9. Note that PBS-2 will unlikely be used due to its location near an oyster reef. Other potential borrow sources include the area to the northwest of Site 2 (which will require additional geotechnical investigations), and the sandy substrate along the northern portion of Site 4B (which will require UXO removal).

- *Site Access & Facilities:* For planning purposes, one spillway was provided per 500 acres of the site area. It was assumed that the site would be accessed through the deepest portion of the alignment. In addition, a service dock was also included.

- *Site Capacity & Operational Life:* The calculation of site capacity and operational life involves three primary considerations: (i) volume occupied by dredged material (accounts for material bulking during dredging, and consolidation and desiccation of dredged material following placement at the site), (ii) placement rates and lift thickness, and (iii) site area & site capacity-dike elevation relationship. For the analysis in this report, the bulking factor was assumed as 1.25, and a volume occupied (V.O.) ratio of 1.0 was assumed below water and a value of 0.6 was assumed above water. Also, as directed by MPA, an annual placement rate of 4.0 million cy was considered for analysis. Finally, an allowance of 3.0 ft was provided for in site capacity computations to account for ponding and freeboard.

6.2.1 Site Design Options

Several design options were considered initially for the various sites in order to generate a range of planning level numbers. Site areas were varied from 500 to 2,000 acres (in 500 acre increments), and dike heights were varied from 10 to 40 ft (in 10 ft increments), except for 3-S (subaqueous alternative, with dike heights ranging from -5 to -20 ft). The results are summarized in Figures 6-1 through 6-7.

In general, site capacity and operational life varied from approximately 19 to 234 mcy, and 5 to 58 years, respectively, for Site 1. For Site 2, site capacity and operational life varied from approximately 28 to 260 mcy, and 7 to 65 years, respectively. For Site 3, site capacity and operational life varied from approximately 31 to 277 mcy, and 8 to 69 years, respectively, and for Site 3-S; they varied from approximately 3 to 65 mcy, and 0.8 to 16 years, respectively. For Site 4A, site capacity and operational life varied from approximately 24 to 239 mcy, and 5 to 60 years, respectively. For Site 4B, site capacity and operational life varied from approximately 16 to 223 mcy, and 4 to 56 years, respectively, and for Site 4B-R, they varied from approximately 20 to 116 mcy, and 5 to 29 years, respectively.

6.2.2 Optimized Site Design

As directed by the MPA, the site design options developed initially were optimized for a 20-year operational life, with a resultant capacity of approximately 80 mcy. Two dike cross-sections were developed for each alternative, based on the exposure to wave attack (except 3-S, the subaqueous alternative). The location of the sections are illustrated in Plates A-3 through A-6. The results are summarized below.

6.2.2.1 Site 1

The optimized design alternatives for Site 1 are summarized in Table 6-1 and illustrated in Plate A-3. The resulting annual lift thickness at the site ranges from 2.9 to 3.9 ft for the two alternatives. Two dike sections were designed with respect to coastal protection, namely dike sections A and B. Dike Section A is designed for exposure to waves originating from the longest fetch direction (i.e., the south-southwest). Dike Section B is designed for exposure to waves originating from the shorter fetch directions (i.e., the north, west, and east). For Site 1, Dike Section A consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 8000 lbs, d_{50} = 3.75 ft, layer thickness = 7.5 ft, and (iii) Slope Underlayer: 800 lbs, d_{50} = 1.75 ft, layer thickness = 3.5 ft. Dike Section B consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 3000 lbs, d_{50} = 2.5 ft, layer thickness = 5.0 ft, and (iii) Slope Underlayer: 300 lbs, d_{50} = 1.25 ft, layer thickness = 2.5 ft. Details of the dike section can be obtained from Plate A-10.

6.2.2.2 Site 2

The optimized design alternatives for Site 2 are summarized in Table 6-1 and illustrated in Plate A-4. The resulting annual lift thickness at the site ranges from 2.6 to 2.9 ft for the two alternatives. Two dike sections were designed with respect to coastal protection, namely dike sections A and B. Dike Section A is designed for exposure to waves originating from the longest fetch direction (i.e., the south-southwest). Dike Section B is designed for exposure to waves originating from the shorter fetch directions (i.e., the north, west, and east). For Site 2, Dike Section A consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 8000 lbs, d_{50} = 3.75 ft, layer thickness = 7.5 ft, and (iii) Slope Underlayer: 800 lbs, d_{50} = 1.75 ft, layer thickness = 3.5 ft. Dike Section B consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 3000 lbs, d_{50} = 2.5 ft, layer thickness = 5.0 ft, and (iii) Slope Underlayer: 300 lbs, d_{50} = 1.25 ft, layer thickness = 2.5 ft. Note that Site 2 also includes a 158-210 ft berm and a 10 ft undercut beneath the dikes due to poor foundation properties, as recommended by the geotechnical consultant (E2Si, 1997). Details of the dike section can be obtained from Plate A-11.

6.2.2.3 Sites 3 and 3-S

The optimized design alternatives for Site 3 are summarized in Table 6-1 and illustrated in Plate A-5. The resulting annual lift thickness at the site ranges from 2.9 to 3.2 ft for the two island alternatives for Site 3, and 1.0 ft for Alternative 3-S. Two dike sections were designed with respect to coastal protection, namely dike sections A and B. Dike Section A is designed for exposure to waves originating from the longest fetch direction (i.e., the south-southwest). Dike Section B is designed for exposure to waves originating from the shorter fetch directions (i.e., the north, west, and east). For Alternatives 3-1 and 3-2, Dike Section A consists of the following: (i) Toe: 500 lbs armor, d_{50}

= 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 8000 lbs, d_{50} = 3.75 ft, layer thickness = 7.5 ft, and (iii) Slope Underlayer: 800 lbs, d_{50} = 1.75 ft, layer thickness = 3.5 ft. Dike Section B consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 3000 lbs, d_{50} = 2.5 ft, layer thickness = 5.0 ft, and (iii) Slope Underlayer: 300 lbs, d_{50} = 1.25 ft, layer thickness = 2.5 ft. Note that Site 3 also includes a 205-260 ft berm and a 15 ft undercut beneath the dikes due to poor foundation properties, as recommended by the geotechnical consultant (E2Si, 1997). Details of the dike sections are shown in Plate A-12.

For Site 3-S (subaqueous), a stepped quarry run dike construction was used as shown in Plate A-13. Note that Site 3-S will not require any undercut due to the lower stress induced by the smaller dike elevation (-10 ft MLLW). However, Site 3-S would also most likely require the use of a sand cap or equivalent upon site closure in order to minimize potential sediment resuspension and release during storm events. For this report, a 3 ft sand cap with four partial renourishments was assumed for costing purposes.

6.2.2.4 Site 4A

The optimized design alternatives for Site 4A are summarized in Table 6-1 and illustrated in Plate No. A-6. The resulting annual lift thickness at the site ranges from 2.1 to 2.4 ft for the two alternatives. Two dike sections were designed with respect to coastal protection, namely dike sections A and B. Dike Section A is designed for exposure to waves originating from the longest fetch direction (i.e., the south-southwest). Dike Section B is designed for exposure to waves originating from the shorter fetch directions (i.e., the north, west, and east). For Site 4A, Dike Section A consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 8000 lbs, d_{50} = 3.75 ft, layer thickness = 7.5 ft, and (iii) Slope Underlayer: 800 lbs, d_{50} = 1.75 ft, layer thickness = 3.5 ft. Dike Section B consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 3000 lbs, d_{50} = 2.5 ft, layer thickness = 5.0 ft, and (iii) Slope Underlayer: 300 lbs, d_{50} = 1.25 ft, layer thickness = 2.5 ft. Note that Site 4A also includes a 154-236 ft berm and a 10 ft undercut beneath the dikes due to poor foundation properties, as recommended by the geotechnical consultant (E2Si, 1997). Details of the dike section can be obtained from Plate A-14.

6.2.2.5 Sites 4B and 4B-R

The optimized design alternatives for Sites 4B and 4B-R are summarized in Table 6-1 and illustrated in Plate No. A-6. The resulting annual lift thickness at the site ranges from 2.8 to 3.8 ft for the two alternatives for 4B, and 4.0 to 4.6 ft for 4B-R. Two dike sections were designed with respect to coastal protection, namely dike sections A and B. Dike Section A is designed for exposure to waves originating from the longest fetch direction (i.e., the south-southwest). Dike Section B is designed for exposure to waves originating from the shorter fetch directions (i.e., the north, west, and east).

For Site 4B, Dike Section A consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 8000 lbs, d_{50} = 3.75 ft, layer thickness = 7.5 ft, and (iii) Slope Underlayer: 800 lbs, d_{50} = 1.75 ft, layer thickness = 3.5 ft. Dike Section B consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 3000 lbs, d_{50} = 2.5 ft, layer thickness = 5.0 ft, and (iii) Slope Underlayer: 300 lbs, d_{50} = 1.25 ft, layer thickness = 2.5 ft. Note that all the weak foundation materials under the dikes at Site 4B will be removed and backfilled (estimated average undercut thickness of 10 ft), therefore, a bench is not required at Site 4B.

For Site 4B-R, Dike Section A consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 8000 lbs, d_{50} = 3.75 ft, layer thickness = 7.5 ft, and (iii) Slope Underlayer: 800 lbs, d_{50} = 1.75 ft, layer thickness = 3.5 ft. Dike Section B consists of the following: (i) Toe: 500 lbs armor, d_{50} = 1.5 ft, layer thickness = 3 ft; quarry run underlayer, (ii) Slope Armor: 3000 lbs, d_{50} = 2.5 ft, layer thickness = 5.0 ft, and (iii) Slope Underlayer: 300 lbs, d_{50} = 1.25 ft, layer thickness = 2.5 ft. Note that Site 4B-R also includes a 123-210 ft berm and a 10 ft undercut beneath the dikes due to poor foundation properties, as recommended by the geotechnical consultant (E2Si, 1997). Details of the dike sections can be obtained from Plate A-15 and A-16 for 4B and 4B-R, respectively.

6.3 Site Construction and Operation

Dredged material containment sites may be constructed using several techniques including bottom dump barges, direct placement using pipelines from hydraulic dredges, pump-out from hydraulic unloaders, and using tremie pipes. Training dikes are commonly used for hydraulic placement of dike fill, to provide better control of the placed material within the dike section. Once a section of the dike fill is placed, densification of the fill and shoreline stabilization work begins.

Construction techniques and borrow sources used for the planning and costing of the island sites, are described in sections 6.3.1 through 6.3.5. For this report, it is assumed that initial construction dike fill material is placed with a hydraulic dredge. Also, it is assumed that future maintenance materials are dredged/transported by clamshell/barge and placed within the island site by hydraulic unloader (except the subaqueous Site 3-S, which will use direct placement from barges/scows). This report assumes that, once the maintenance dredged material placed at the site exceeds the elevation of the bay water level, crust management is implemented in order to maximize the operational life of the site. Also, dried crust resulting from such operations could be a valuable source for future dike raising material, resulting in considerable cost savings. Site operation and crust management could be implemented using low ground pressure draglines, and trenchers. These equipment are complimentary in that the dragline will be able to construct a perimeter trench in soft materials where a bulldozer or trencher will not be as effective. A dozer with winch is also required to assist the trenching equipment in maneuvering over the cell surface.

The progress and effectiveness of site construction and operation should be evaluated using site surveys and monitoring procedures. These typically include pre-construction environmental monitoring (contaminants, benthos, biota, etc), pre-construction surveys, during-construction surveys, post-construction surveys, annual surveys, and post-construction environmental monitoring (ground water, TSS, effluent/runoff quality). A detailed monitoring and surveying plan (number, location, and spacing of stations and/or samples) should also be developed based on site-specific factors.

Annual dredging volumes from Baltimore Harbor Outer Channels and the C&D Approach Channel, requiring placement at the site was assumed to be 4.0 mcy, as directed by MPA. The estimated dredging volumes from the individual channels were: (i) 2.04 mcy for the C&D Canal Approach Channel, (ii) 0.32 mcy for the Tolchester Channel, (iii) 0.05 mcy for the Swan Point Channel, (iv) 0.43 mcy for the Brewerton Extension Channel, (v) 0.86 mcy for the Craighill Upper Range Channel (including Craighill Angle, Craighill Upper Range, and Cutoff Angle Channels), and (vi) 0.3 mcy for the Craighill Entrance Channel (including Craighill Entrance and Craighill Channels). Weighted average one-way transport distances were computed from these channels to the sites based on dredging quantities and the shortest distance from the centroid of the dredging location to the sites, giving due consideration of the draft requirements for the barges. The dredging volumes and the weighted average one way transport distances from the channels to the sites are given in Table 6-2.

6.3.1 Site 1

Site 1 will be constructed using borrow material from PBS-3 (see Plate A-9) using a hydraulic dredge. The required dike fill volume for initial construction of this site varies from approximately 2.5 to 2.9 mcy, which is readily available from PBS-3. The armor stone, underlayer stone, and quarry run for dike stabilization will be placed mechanically at the site. It is assumed that maintenance dredged material from the channels will be dredged using a clamshell and placed at the site using a hydraulic unloader. The weighted average transport distance to the site is approximately 10.9 nm. Once the material is placed at the site, it can be managed using draglines, trenchers, and dozers.

6.3.2 Site 2

Site 2 could be constructed using borrow material from PBS-3 or PBS-4 (see Plate A-9) using a hydraulic dredge. It may also be possible to use the sands from the northwest area along the boundary of Site 2, which will require further geotechnical investigations. For costing purposes, it was assumed that the borrow material would be taken from PBS-3. The required dike fill volume for initial construction of this site varies from approximately 10 to 11 mcy, which is readily available from PBS-3. The armor stone, underlayer stone and quarry run for shoreline stabilization will be placed mechanically at the site. It is assumed that maintenance dredged material from the channels will be dredged using a clamshell and placed at the site using a hydraulic unloader.

The weighted average transport distance to the site is approximately 10.4 nm. Once the material is placed at the site, it can be managed using draglines, trenchers, and dozers.

6.3.3 Sites 3 and 3-S

Site 3 will be constructed using borrow material from PBS-4 and PBS-5 (see Plate A-9) using a hydraulic dredge. The required dike fill volume for initial construction of this site varies from approximately 19 to 20 mcy, which is readily available from PBS-4 and PBS-5. The armor stone, underlayer stone and quarry run for shoreline stabilization will be placed mechanically at the site. It is assumed that maintenance dredged material from the channels will be dredged using a clamshell and placed at the site using a hydraulic unloader. The weighted average transport distance to the site is approximately 12 nm. Once the material is placed at the site, it can be managed using draglines, trenchers, and dozers.

The subaqueous option, Site 3-S, will be constructed using borrow material from PBS-4 & PBS-5 (see Plate A-9) using a hydraulic dredge. The required dike fill volume for initial construction of this site is approximately 2.9 mcy, which is readily available from PBS-4 & PBS-5. The quarry run for dike construction will be placed mechanically at the site. It is assumed that maintenance dredged material from the channels will be dredged using a clamshell and directly placed at the site using scows and/or hoppers. The weighted average transport distance to Site 3-S is approximately 12.5 nm.

Sand for capping the site following site use could be obtained from the identified borrow sources, particularly PBS-3, PBS-4, PBS-5, Site 4B, and the northwest area along the boundary of Site 2. However, the last two sources listed will require additional investigations. It is assumed that the cap can be placed from the surface using barges and/or scows.

6.3.4 Site 4A

Site 4A will be constructed using borrow material from PBS-3 (see Plate A-9) using a hydraulic dredge. The required dike fill volume for initial construction of this site varies from approximately 11 to 12 mcy, which is readily available from PBS-3. The armor stone, underlayer stone and quarry run for shoreline stabilization will be placed mechanically at the site. It is assumed that maintenance dredged material from the channels will be dredged using a clamshell and placed at the site using a hydraulic unloader. The weighted average transport distance to the site is approximately 10 nm. Once the material is placed at the site, it can be managed using draglines, trenchers, and dozers. Note additional UXO investigations will be required before construction can be undertaken at that this site.

6.3.5 Sites 4B and 4B-R

Site 4B (and Site 4-B-R) will be constructed using borrow material from PBS-3 (see Plate A-9) using a hydraulic dredge. The required dike fill volume for initial construction of 4B varies from approximately 3.0 to 3.5 mcy, while that of 4B-R varies from approximately 4.7 to 5.0 mcy. These quantities are readily available from PBS-3. Another potential borrow source is the sandy substrate along the northern portion of Site 4B. However, due to the need for additional UXO investigations and associated complexities, the borrow material for Sites 4B and 4B-R were assumed to be taken from PBS-3, for costing purposes. The armor stone, underlayer stone and quarry run for shoreline stabilization will be placed mechanically at the site. It is assumed that maintenance dredged material from the channels will be dredged using a clamshell and placed at the site using a hydraulic unloader. The weighted average transport distance to Sites 4B and 4B-R is approximately 11.6 nm. Once the material is placed at the site, it can be managed using draglines, trenchers, and dozers. Additional UXO investigations will be required before construction can be undertaken at that this site.

6.4 Site Costs

The site costs for the various island alternatives consists of the following items:

- *Site Development Costs:* This refers to the costs for construction and operation of the site, and includes initial site construction costs, annual costs, and dike raising costs, as described below.

- *Initial Site Construction Costs:* This includes construction of the dikes to the desired initial elevation, dike stabilization costs (armor, underlayer, and toe protection), installation of spillways/outlet structures, and site infrastructure.

- *Annual Costs:* This includes site dewatering and management, operation and maintenance (O&M), crust management, and site monitoring for the life of the site.

- *Dike Raising Costs:* This includes costs for incremental raising of the dikes using dried dredged material crust, based on geotechnical considerations.

- *Dredging/Transport and Placement Costs:* This includes costs for dredging the navigation channels, transport to the placement site, and unloading of the dredged material at the site for the design life of the site.

Based on the above factors, the *total costs* for the operational life of the facility was generated as the sum of the site development costs and dredging, transport, and placement costs. From this information, the cost per cubic yard of capacity for the site was generated, which was used for comparing the various island alternatives.

Site costs can be compared through two approaches:

- **Total Site Costs**, which is made up of site development costs, and dredging/transport and placement costs over the operational life of the sites, and

- **Present Worth of Site Costs**, which consists of the same site development costs, and dredging/transport and placement costs over the operational life of the sites, discounted based on an annual borrowing rate.

6.4.1 Total Site Costs

The Alternative Analysis - Costs Matrix for the total site costs in constant 1997 dollars is presented in Table 6-3. Details of the cost tables for the individual alternatives and the material quantities used for developing the estimates can be obtained from GBA (1997).

Site development costs and total costs (in constant 1997 dollars) for Site 1-1 were $98 million and $562 million, respectively, resulting in unit cost of $1.23/cy and $7.05/cy, respectively. For Site 1-2, the site development costs and total costs (in constant 1997 dollars) were $88 million and $552 million, respectively, with unit cost of $1.10/cy and $6.91/cy, respectively.

Site development costs and total costs (in constant 1997 dollars) for Site 2-1 were $226 million and $685 million, respectively, resulting in unit cost of $2.81/cy and $8.54/cy, respectively. For Site 2-2, the site development costs and total costs (in constant 1997 dollars) were $210 million and $669 million, respectively, with unit cost of $2.63/cy and $8.37/cy, respectively.

Site development costs and total costs (in constant 1997 dollars) for Site 3-1 were $345 million and $820 million, respectively, resulting in unit cost of $4.32/cy and $10.26/cy, respectively. For Site 3-2, the site development costs and total costs (in constant 1997 dollars) were $332 million and $806 million, respectively, with unit cost of $4.13/cy and $10.05/cy, respectively.

For the subaqueous option (3-S), the site development costs and total costs (in constant 1997 dollars) were $300 million and $572 million, respectively, resulting unit costs of $3.76/cy and $7.17/cy, respectively. Note that the cost estimate for this site assumes that the site will most likely require a sand cap or equivalent upon closure due to environmental requirements. Assuming a 3 ft sand cap following site use, the costs for four partial renourishments are included in the estimate.

Site development costs and total costs (in constant 1997 dollars) for Site 4A-1 were $345 million and $800 million, respectively, resulting in unit cost of $4.30/cy and $9.97/cy, respectively. For Site 4A-2, the site development costs and total costs (in constant 1997 dollars) were $311 million and $766 million, respectively, with unit cost of $3.86/cy and $9.52/cy, respectively.

Site development costs and total costs (in constant 1997 dollars) for Site 4B-1 were $241 million and $712 million, respectively, resulting in unit cost of $3.02/cy and $8.93/cy, respectively. For Site 4B-2, the site development costs and total costs (in constant 1997 dollars) were $192 million and $663 million, respectively, with unit cost of $2.40/cy and $8.28/cy, respectively.

For the modified alignment of Site 4B-R-1, the site development costs and total costs (in constant 1997 dollars) were $198 million and $433 million, respectively, resulting in unit cost of $4.95/cy and $10.82/cy, respectively. For Site 4B-R-2, the site development costs and total costs (in constant 1997 dollars) were $187 million and $423 million, respectively, resulting in a unit cost of $4.68/cy and $10.56/cy, respectively.

Note that costs for Sites 4A, 4B, and 4B-R also include a planning level estimate of costs for investigation and removal of UXO from the sites, developed based on the average of the higher end cost estimates supplied by APG and other contractors for similar investigations at other sites. The UXO costs were estimated to be $80,000/acre for 10 ft sweeping depths under the dike footprint and potential borrow sources. At other locations, $20,000/acre was used for a 2 ft surficial sweep.

6.4.2 Present Worth Site Costs

Present worth of the site development costs, and dredging/transport and placement costs over the operational life of the sites was developed as indicated in Table 6-4. The initial construction costs, annual costs and dike raising costs are the same in this analysis as those used in the total site costs analysis. The discount rate used was 5%, which is approximately the current Maryland Department of Transportation (MDOT) borrowing rate. Note that the discount rate accounts for an inflation factor over the duration of the project since all cost items are expected to appreciate at the same rate, and hence, inflation was not considered separately in the analysis (Bower, 1997). A comparison of the total costs (in constant 1997 dollars) to the present worth costs (in discounted 1997 dollars) is presented in Table 6-5.

Site development costs and total costs (in discounted 1997 present worth dollars) for Site 1-1 were $81 million and $343 million, respectively, resulting in unit cost of $1.01/cy and $4.30/cy, respectively. For Site 1-2, the site development costs and total costs (in discounted 1997 present worth dollars) were $72 million and $334 million, respectively, with unit cost of $0.90/cy and $4.18/cy, respectively.

Site development costs and total costs (in discounted 1997 present worth dollars) for Site 2-1 were $200 million and $459 million, respectively, resulting in unit cost of $2.50/cy and $5.73/cy, respectively. For Site 2-2, the site development costs and total costs (in discounted 1997 present worth dollars) were $186 million and $445 million, respectively, with unit cost of $2.32/cy and $5.57/cy, respectively.

Site development costs and total costs (in discounted 1997 present worth dollars) for Site 3-1 were \$312 million and \$580 million, respectively, resulting in unit cost of \$3.90/cy and \$7.26/cy, respectively. For Site 3-2, the site development costs and total costs (in discounted 1997 present worth dollars) were \$299 million and \$567 million, respectively, with unit cost of \$3.73/cy and \$7.07/cy, respectively.

For the subaqueous option (3-S), the site development costs and total costs (in discounted 1997 present worth dollars) were \$135 million and \$289 million, respectively, resulting unit costs of \$1.70/cy and \$3.62/cy, respectively. Note that the cost estimate for this site assumes that the site will most likely require a sand cap or equivalent upon closure due to environmental requirements. Assuming a 3 ft sand cap following site use, the costs for four partial renourishments are included.

Site development costs and total costs (in discounted 1997 present worth dollars) for Site 4A-1 were \$310 million and \$568 million, respectively, resulting in unit cost of \$3.86/cy and \$7.07/cy, respectively. For Site 4A-2, the site development costs and total costs (in discounted 1997 present worth dollars) were \$279 million and \$536 million, respectively, with unit cost of \$3.46/cy and \$6.66/cy, respectively.

Site development costs and total costs (in discounted 1997 present worth dollars) for Site 4B-1 were \$213 million and \$479 million, respectively, with unit cost of \$2.68/cy and \$6.01/cy, respectively. For Site 4B-2, the site development and total costs (in discounted 1997 present worth dollars) were \$168 million and \$434 million, respectively, with unit cost of \$2.10/cy and \$5.42/cy, respectively.

For the modified alignment of Site 4B-R-1, the site development costs and total costs (in discounted 1997 present worth dollars) were \$181 million and \$346 million, respectively, resulting in unit cost of \$4.52/cy and \$8.64/cy, respectively. For Site 4B-R-2, the site development costs and total costs (in discounted 1997 present worth dollars) were \$168 million and \$333 million, respectively, resulting in a unit cost of \$4.21/cy and \$8.33/cy, respectively.

Note that the costs for Sites 4A, 4B, and 4B-R also includes a planning level estimate of costs for investigation and removal of UXO from the sites, developed based on the average of the higher end cost estimates supplied by APG and other contractors for similar investigations at other sites. The UXO costs were estimated to be \$80,000/acre for 10 ft sweeping depths under the dike footprint and potential borrow sources. At other locations, \$20,000/acre was used for a 2 ft surficial sweep.

6.4.3 Estimated Costs for Other Potential Site Alternatives

In order to evaluate other potential site alternatives, the detailed cost estimates developed in this section were extrapolated to a range of areas for each of the sites. Values for initial construction costs, site development costs, and total costs were computed per linear feet of the dike for each of the sites. These values were then applied to a range of areas to arrive at planning level estimates for the costs for building alternate site alignments. The resulting cost plots are illustrated in Figures 6-8 through 6-10. Note that these estimates assume that the dikes will be raised to the final elevations possible for the sites, based on the gain in strength of the foundation material due to consolidation, and geotechnical considerations.

6.5 Comparison of Site Costs

6.5.1 Cost-Based Site Comparison

The site costs of the alternatives are a function of the following factors:

- Geotechnical (foundation strength, and borrow material quality and quantity),
- Environmental (environmental requirements, and mitigation projects, if any),
- Coastal (hydrodynamic factors, and dike slope protection), and
- Dredging (dike design, site engineering, dredging, transport, and placement).

For example, foundation quality and hydrodynamics directly affect the initial construction costs. Environmental sensitivity, on the other hand, could affect site development costs (effluent monitoring, potential closure requirements, and mitigation projects, if any). Finally, dredging, transport and material placement costs directly affect the total costs.

For a cost-based analysis of alternatives, total costs and unit costs for the alternative (i.e., total alternative costs) were considered, which included the following:

- Initial construction costs (i.e., the costs to make the site operational),
- Site development costs (includes initial construction costs, annual costs, and dike raising costs), and
- Dredging/transport and placement costs.

6.5.2 Comparison Matrix

The Alternative Analysis - Costs Matrices are presented in Table 6-3 through 6-5. For a cost-based analysis of alternatives, the two key components of the total alternative costs (site development costs, and dredging costs) were individually considered. A cost-based comparison matrix was developed using the estimated costs for each alternative, with a value of "1" being the least expensive option. A value of "11" on the other hand, is the most expensive option, from a cost-based analysis. While total costs is a good indicator of the overall costs of the project, it may not be quite reflective of the costs that the project sponsor(s) will have to bear. That cost would be more represented by the site development costs, which includes the initial construction costs, annual costs (for site management, maintenance, and environmental monitoring), and dike raising costs. Therefore, the sites were compared based on initial construction costs, site development costs (in constant 1997 dollars and in present worth 1997 discounted dollars), and total costs (in constant 1997 dollars and in present worth 1997 discounted dollars), as shown in Table 6-6.

Note that site 4B-R was not included in this analysis due to its limited site capacity (40 mcy, yielding a site life of only 10 years). It was therefore assumed that this site would have to be combined with another smaller site option in order to meet the projected MPA dredging demand.

6.5.3 Cost Comparison Results

From this analysis, clearly Sites 1-2, 1-1, 3-S, 4B-2, and 2-2 are the least expensive options, from a total cost point of view. Of these, Sites 1-2 and 1-1 are the least expensive alternatives, followed closely by 3-S (even after accounting for a sand cap following closure at this site). Considering total present worth costs (1997 discounted dollars), Site 3-S is the least expensive option. However, Sites 1-2 and 1-1 are the least expensive options based on initial construction and present worth site development costs. These are more representative of the costs the project sponsor(s) will need to bear. Also, additional investigations would be needed to determine the suitability of Site 3-S, including water column turbidity, sediment resuspension, potential release during storm events, and cap requirements. Therefore, considering site development costs only (which is more related to the costs that the project sponsor(s) will have to bear), Sites 1-2 and 1-1 are the least expensive options.

Table 6-1 Optimized Site Characteristics

Site Designation*	Surface Area (Acres)	Avg. Water Depth ** (ft. mllw)	Final Dike Elevation (ft. mllw)	Total Dike Height (ft)	Volume Occupied Ratio	Design Capacity (Mcy)	Site Life (Yrs)	Annual Lift Thickness (ft.)
1 - 1	1060	12	25	37	0.73	80	20	2.9
1 - 2	790	12	35	47	0.70	80	20	3.9
2 - 1	1195	23	15	38	0.84	80	20	2.6
2 - 2	1075	23	18	41	0.82	80	20	2.9
3 - 1	1065	28	15	43	0.86	80	20	2.9
3 - 2	975	28	18	46	0.84	80	20	3.2
3-S	3000	29.5	-10	19.5	1.00	80	20	1.0
4A - 1	1475	15	15	30	0.80	80	20	2.1
4A - 2	1300	15	18	33	0.78	80	20	2.4
4B - 1	1125	9	25	34	0.71	80	20	2.8
4B - 2	825	9	35	44	0.68	80	20	3.8
4B - R - 1	780	13	15	28	0.79	40	10	4.0
4B - R - 2	680	13	18	31	0.77	40	10	4.6

Notes:

1. V.O. Ratio prorated based on 1.0 below water and 0.6 above water.
2. Dredged material placement demand = 4 Mcy per year.
3. Design Capacity is based on ponding and freeboard of 3ft.
4. Lift thickness includes placement of 4 Mcy per year and estimated initial bulking of 1.25.
5. Note that sites 4B - R - 1 and 4B - R - 2 would have to be combined with another smaller site option in order to meet the projected MPA dredging demand.
6. * Each site includes two alternatives, one for each of two dike heights (e.g.: 1 - 1 & 1 - 2). The first alternative assumes no long-term gain in foundation strength due to consolidation, while the second alternative does assume such a gain in foundation strength.
7. ** Corresponds to average water depth within the site.
8. All alternatives except 1 - 1, 1 - 2 and 3 - S include foundation undercut and replacement with sand fill.
9. Final dike elevation for 4B - 1 and 4B - 2 assumes that the top 10 ft. of poor foundation materials will be undercut and replaced with sand fill.

Table 6-2 Annual Dredging Volumes & Transport Distances

Site No.	C & D Canal Approach Channel (2.04 Mcy)		Tolchester Channel (0.32 Mcy)		Swan Point Channel (0.05 Mcy)		Brewerton Extension Channel (0.43 Mcy)		Craighill Upper Range Channel (0.86 Mcy)		Craighill Entrance Channel (0.3 Mcy)		Total	Weighted Distance
	Dist. (nm)	(Mcy-nm)	Dist. (nm)	(Mcy-nm)	Dist. (nm)	(Mcy-nm)	Dist. (nm)	(Mcy-nm)	Dist. (nm)	(Mcy-nm)	Dist. (nm)	(Mcy-nm)	(Mcy-nm)	(Nm)
1	9.7	19.83	4.3	1.36	10.5	0.52	9.9	4.25	15.0	12.90	16.4	4.92	43.79	10.9
2	12.9	26.28	1.3	0.42	5.7	0.28	5.1	2.20	10.2	8.79	11.6	3.49	41.46	10.4
3	16.5	33.64	4.9	1.57	1.6	0.08	4.8	2.06	9.9	8.51	7.5	2.25	48.11	12.0
3 - S	17.3	35.27	5.7	1.83	2.4	0.12	5.6	2.40	10.7	9.19	4.5	1.36	50.17	12.5
4A	5.5	11.23	6.7	2.14	12.9	0.65	12.3	5.30	17.4	15.00	18.8	5.65	39.96	10.0
4B	7.7	15.79	7.7	2.47	13.9	0.70	13.3	5.73	18.4	15.86	19.8	5.95	46.49	11.6
4B - R	7.7	15.79	7.7	2.47	13.9	0.70	13.3	5.73	18.4	15.86	19.8	5.95	46.49	11.6

<u>Notes:</u>

1. Dredging quantities are the estimated annual maintenance dredging volume (Mcy per year). This data was extrapolated from the Poplar Island Alternative Site Layout Report (GBA and M&N, 1996), the MPA Draft Master Plan (MPA, 1989), and personal communication with USACE, Baltimore District.
2. Distances listed are one way haul from the centroid of each dredging area to the unloading area for each site.
3. "cy-nm" is the distance (nm) multiplied by the dredging quantity (cy) for each dredging site.
4. Weighted Distance (nm) is the total of all cy-nm's divided by the annual dredging volume (4.0 Mcy).
5. The dredging quantities for Craighill Upper Range Channel includes that of Craighill Angle, Craighill Upper Range and Cut Off Angle.
6. The dredging quantities for Craighill Entrance Channel includes that of Craighill Entrance and Craighill Channel.

Table 6-3 Alternative Analysis - Cost Matrix (values in constant 1997 dollars)

Site Designation*	Net Site Capacity (Mcy)	Site Life (Years)	INITIAL CONSTRUCTION COSTS		Annual Costs	Dike Raising	SITE DEVELOPMENT COSTS		Dredging/Transport & Placement Costs		TOTAL COSTS	
			$ Million	$ / CY	$ Million	$ Million	$ Million	$ / CY	$ Million	$ / CY	$ Million	$ / CY
1 - 1	80	20	70	0.88	24.6	2.67	98	1.23	464	5.82	562	7.05
1 - 2	80	20	62	0.77	22.2	4.31	88	1.10	464	5.81	552	6.91
2 - 1	80	20	199	2.48	26.0	0.51	226	2.81	459	5.73	685	8.54
2 - 2	80	20	184	2.30	24.9	1.20	210	2.63	459	5.74	669	8.37
3 - 1	80	20	320	4.01	24.8	0.32	345	4.32	474	5.94	820	10.26
3 - 2	80	20	307	3.82	24.0	0.99	332	4.13	474	5.92	806	10.05
3-S	80	20	89	1.12	12.1	199 **	300	3.76	272	3.41	572	7.17
4A - 1	80	20	316	3.94	28.2	0.76	345	4.30	455	5.67	800	9.97
4A - 2	80	20	283	3.51	26.8	1.50	311	3.86	455	5.66	766	9.52
4B - 1	80	20	213	2.67	25.4	2.91	241	3.02	471	5.90	712	8.93
4B - 2	80	20	165	2.06	22.7	4.61	192	2.40	471	5.88	663	8.28
*** 4B - R - 1	40	10	186	4.64	11.8	0.41	198	4.95	235	5.88	433	10.82
*** 4B - R - 2	40	10	173	4.31	11.3	3.46	187	4.68	235	5.88	423	10.56

Notes:

1. Initial Construction Costs include dike construction, spillways and other facilities.
2. Annual Costs include site management, O&M, material drying, and site monitoring for the operational life of the site.
3. Site Development Costs include initial construction costs, annual costs, and dike raising costs.
4. Dredging Costs include dredging, transport and placement of maintenance material for the operational life of the site.
5. Total Alternative Costs include site development costs plus maintenance dredging costs for the operational life of the site.

* 6. Each site includes two alternatives, one for each of two dike heights (e.g.: 1 - 1 & 1 - 2). The first alternative assumes no long-term gain in foundation strength due to consolidation, while the second alternative does assume such a gain in foundation strength.

** 7. Site 3-S has no dike raising costs; however, site development costs for site 3-S include costs for capping, which are shown here.

*** 8. Note that sites 4B - R - 1 and 4B - R - 2 would have to be combined with another smaller site option in order to meet the projected MPA dredging demand.

9. All alternatives except 1 - 1, 1 - 2 and 3 - S include foundation undercut and replacement with sand fill, which is accounted for in the initial construction costs.
10. Initial construction costs for sites 4A, 4B and 4B - R also include the costs for investigation and removal of UXO's.
11. Annual site maintenance costs after the operational life of the site are not considered in this analysis.
12. Sites 4A, 4B and 4B-R includes costs for UXO investigation, removal and storage at the APG facility at an estimated cost of $80,000/acre for 10 ft sweeping depths under the dike foot print and borrow sources. At other areas, the cost was estimated to be $20,000/acre for a 2 ft surficial sweep.

Table 6-4 Alternative Analysis - Present Worth Costs Matrix (values in discounted 1997 dollars)

Site Designation*	Net Site Capacity (Mcy)	Site Life (Years)	Present Worth Site Development Costs**		Present Worth Dredging/ Transport & Placement Costs		Present Worth Total Costs	
			$ Million	$ / CY	$ Million	$ / CY	$ Million	$ / CY
1 - 1	80	20	81	1.01	262	3.29	343	4.30
1 - 2	80	20	72	0.90	262	3.28	334	4.18
2 - 1	80	20	200	2.50	259	3.24	459	5.73
2 - 2	80	20	186	2.32	259	3.25	445	5.57
3 - 1	80	20	312	3.90	268	3.36	580	7.26
3 - 2	80	20	299	3.73	268	3.34	567	7.07
3 - S	80	20	135	1.70	154	1.92	289	3.62
4A - 1	80	20	310	3.86	257	3.20	568	7.07
4A - 2	80	20	279	3.46	257	3.20	536	6.66
4B - 1	80	20	213	2.68	266	3.34	479	6.01
4B - 2	80	20	168	2.10	266	3.32	434	5.42
4B - R - 1***	40	10	181	4.52	165	4.12	346	8.64
4B - R - 2***	40	10	168	4.21	165	4.12	333	8.33

Notes:

1. Present Worth Costs were based on a discount rate of 5 percent.

* 2. Each site includes two alternatives, one for each of two dike heights (e.g.: 1 - 1 & 1 - 2). The first alternative assumes no long-term gain in foundation strength due to consolidation, while the second alternative does assume such a gain in foundation strength.

** 3. Site 3 - S has no dike raising costs; however, site development costs for site 3 - S includes the costs for capping which is included here.

*** 4. Note that sites 4B - R - 1 and 4B - R - 2 would have to be combined with another smaller site option in order to meet the projected MPA dredging demand.

5. Present Worth Costs were computed based on a discount rate of 5 percent.
6. Site Development Costs include initial construction costs, annual costs, and dike raising costs.
7. Dredging Costs include dredging, transport and placement of maintenance material for the operational life of the site.
8. Total Costs include site development costs plus maintenance dredging costs for the operational life of the site.
9. All alternatives except 1 - 1, 1 - 2, and 3 - S includes foundation undercut and replacement with sand fill, which is accounted for in the which is accounted for in the initial construction costs.
10. Annual site maintenance costs after the operational life of the site are not considered in this analysis.
11. Sites 4A, 4B and 4B-R includes costs for UXO investigation, removal and storage at the APG facility at an estimated cost of $80,000/acre for 10 ft sweeping depths under the dike foot print and borrow sources. At other areas, the cost was estimated to be $20,000/acre for a 2 ft surfacial sweep.

Table 6-5 Summary Costs Matrix (in constant 1997 and Present Worth 1997 discounted dollars)

Site Designation *	Initial Construction Costs (in constant 1997 $ and Present Worth 1997 discounted $)		Site Development Costs**				Total Costs			
			(in constant 1997 $)		(In Present Worth 1997 discounted $)		(in constant 1997 $)		(In Present Worth 1997 discounted $)	
	$ Million	$ / CY	$ Million	$ / CY	$ Million	$ / CY	$ Million	$ / CY	$ Million	$ / CY
1 - 2	62	0.77.	88	1.10	72	0.90	552	6.91	334	4.18
2 - 2	184	2.30	210	2.63	186	2.32	669	8.37	445	5.57
3 - 2	307	3.82	332	4.13	299	3.73	806	10.05	567	7.07
3 - S	89	1.12	300	3.76	135	1.70	572	7.17	289	3.62
4A - 2	283	3.51	311	3.86	279	3.46	766	9.52	536	6.66
4B - 2	165	2.06	192	2.40	168	2.10	663	8.28	434	5.42
4B - R - 2	173	4.31	187	4.68	168	4.21	423	10.56	333	8.33

Notes:

1. Initial Construction Costs include dike construction, spillways and other facilities.
2. Site Development Costs include initial construction costs, annual costs, and dike raising costs.
3. Total Alternative Costs include site development costs plus maintenance dredging costs for the operational life of the site.
4. Present Worth Costs were based on a discount rate of 5 percent.

* 5. All sites have a capacity of 80 MCY and a site life of 20 years, except site 4B - R, which has a capacity of 40 MCY and site life of 10 years.

** 6. Site 3 - S has no dike raising costs; however, site development costs for site 3 - S includes the costs for capping, which is included here.

*** 7. Note that alternatives 4B - R - 1 & 4B - R - 2 would need to be combined with another smaller site option in order to meet the projected MPA dredging demand.

8. Sites 4A, 4B and 4B-R includes costs for UXO investigation, removal and storage at the APG facility at an estimated cost of $80,000/acre.
9. Each site includes two alternatives, one for each of two dike heights (e.g.: 1 - 1 & 1 - 2). Only the Alternative which assumes a long-term gain in foundation strength is included in this table.

Table 6-6 Alternative Analysis - Costs Comparison Matrix

Site Designation*	Surface Area (Acres)	Site Capacity (Mcy)	Site Life (Years)	Initial Construction Costs Comparison**	Site Development Costs Comparison**	Total Costs Comparison**	Present Worth Site Development Costs Comparison**	Present Worth Total Costs Comparison**
1 - 1	1060	80	20	2	2	2	2	3
1 - 2	790	80	20	1	1	1	1	2
2 - 1	1195	80	20	6	5	6	6	6
2 - 2	1075	80	20	5	4	5	5	5
3 - 1	1065	80	20	11	11	11	11	11
3 - 2	975	80	20	9	9	10	9	9
3-S	3000	80	20	3	7	3	3	1
4A - 1	1475	80	20	10	10	9	10	10
4A - 2	1300	80	20	8	8	8	8	8
4B - 1	1125	80	20	7	6	7	7	7
4B - 2	825	80	20	4	3	4	4	4
4B - R - 1	780	40	10	n/a***	n/a***	n/a***	n/a***	n/a***
4B - R - 2	680	40	10	n/a***	n/a***	n/a***	n/a***	n/a***

Notes:

1. Initial Construction Costs include dike construction, spillways and other facilities, and reflects the costs to make the site operational.
2. Annual Costs include site management, O&M, material drying, and site monitoring for the operational life of the site.
3. Site Development Costs include initial construction, annual costs, and dike raising costs.
4. Dredging Costs include dredging, transport and placement of maintenance material for the operational life of the site.
5. Total Costs include site development plus maintenance dredging costs for the operational life of the site.

* 6. Each site includes two alternatives, one for each of two dike heights (e.g.: 1 - 1 & 1 - 2). The first alternative assumes no long-term gain in foundation strength due to consolidation, while the second alternative does assume such a gain in foundation strength.

** 7. The scores for the cost comparison is based on a value of 1 for the least expensive alternative and 11 for the most expensive alternative.

*** 8. 4B - R - 1 and 4B - R - 2 were not included in the analysis due to their smaller site capacity. Note that these sites would have to be combined with another smaller site option in order to meet the projected MPA dredging demand.

9. All alternatives except 1 - 1, 1 - 2 and 3 - S include foundation undercut and replacement with sand fill, which is accounted for in the initial construction costs.
10. Site Development Costs for 3 - S include the costs for a sand cap.
11. Initial Construction Costs for the sites 4A, 4B and 4B - R also include the costs for investigation and removal of UXO's.
12. Annual site maintenance costs after the operational life of the site are not considered in this analysis.
13. Present Worth Costs were computed based on a discount rate of 5 percent.

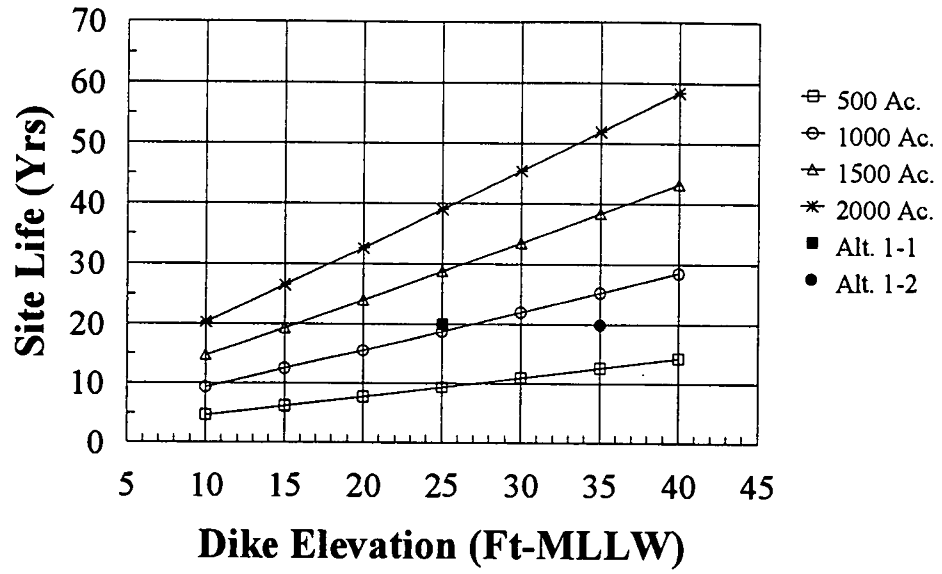

Figure 6-1a - Site Life vs Dike Elevation - Site 1

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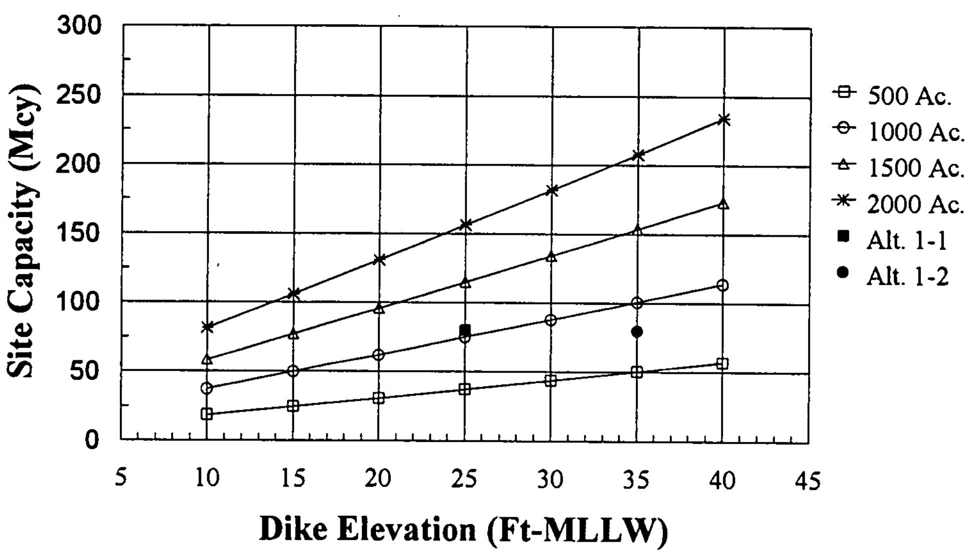

Figure 6-1b - Site Capacity vs Dike Elevation - Site 1

GAHAGAN & BRYANT ASSOCIATES, INC.

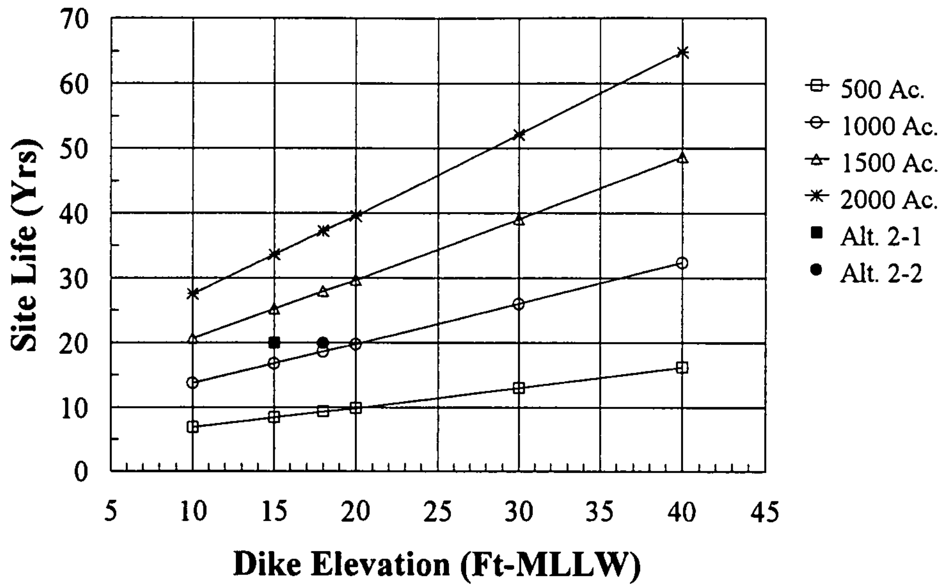

Figure 6-2a - Site Life vs Dike Elevation - Site 2

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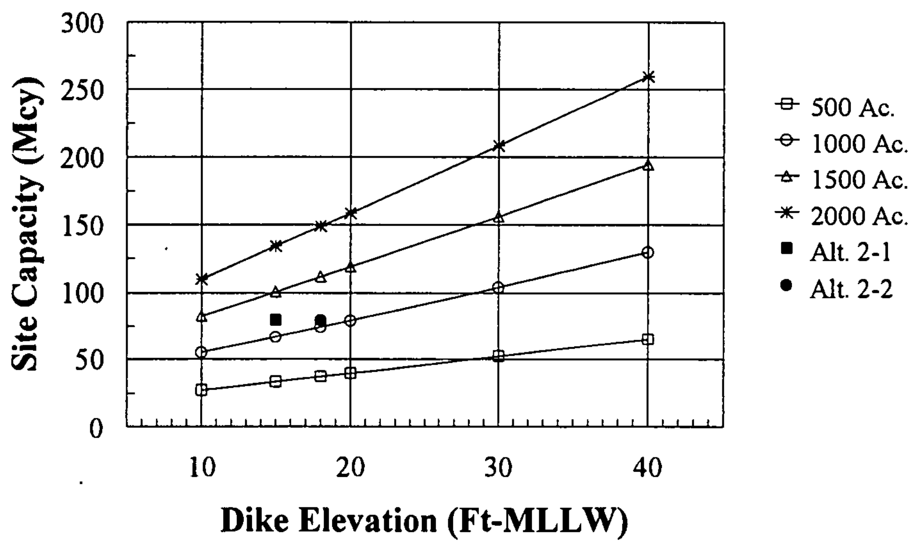

Figure 6-2b - Site Capacity vs Dike Elevation - Site 2

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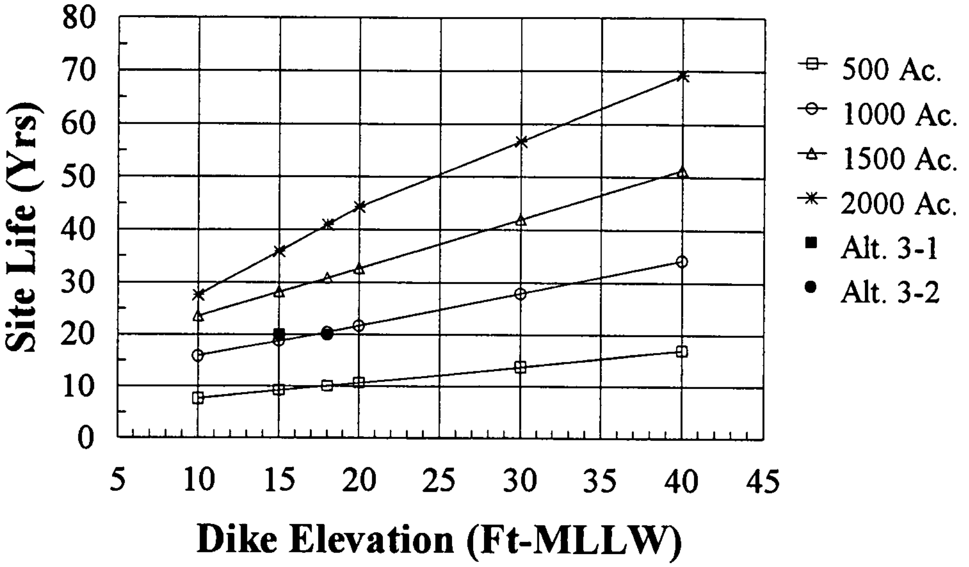

Figure 6-3a - Site Life vs Dike Elevation - Site 3

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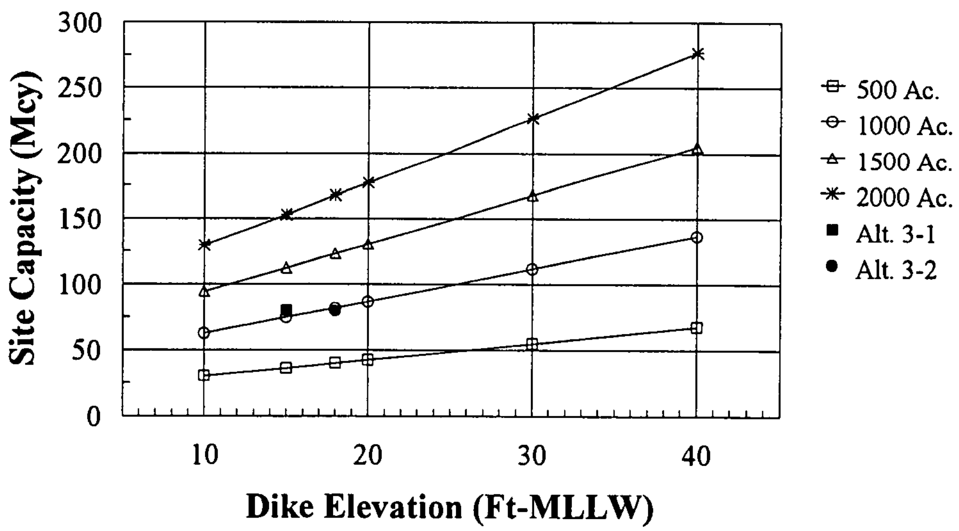

Figure 6-3b - Site Capacity vs Dike Elevation - Site 3

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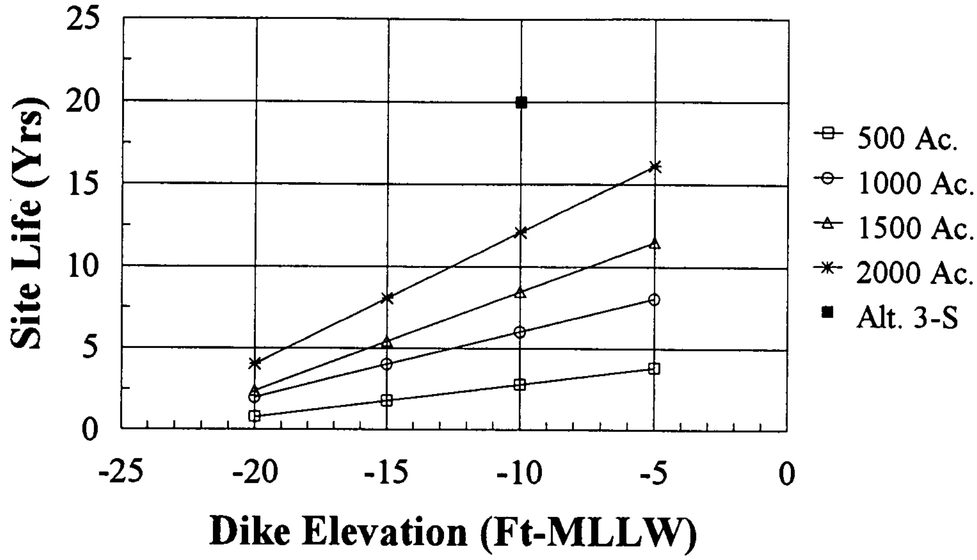

Figure 6-4a - Site Life vs Dike Elevation - Site 3-S

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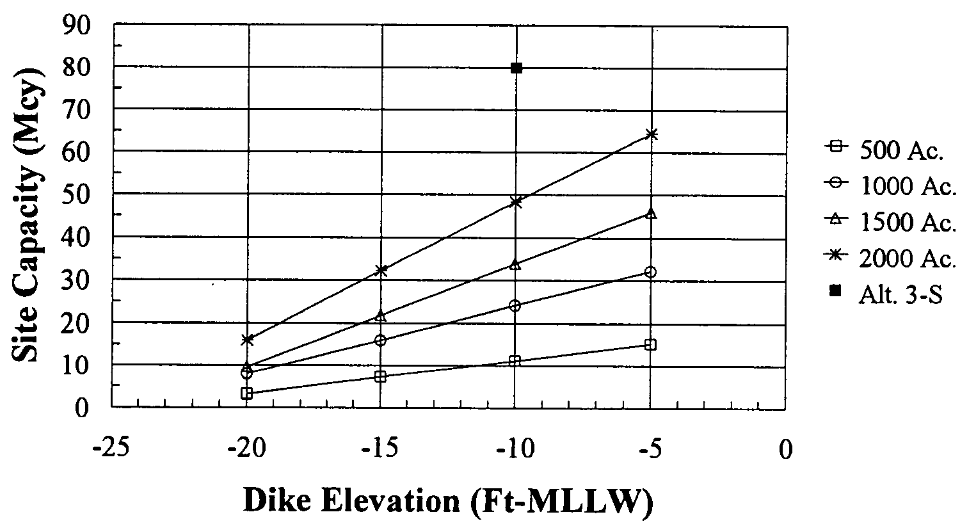

Figure 6-4b - Site Capacity vs Dike Elevation - Site 3-S

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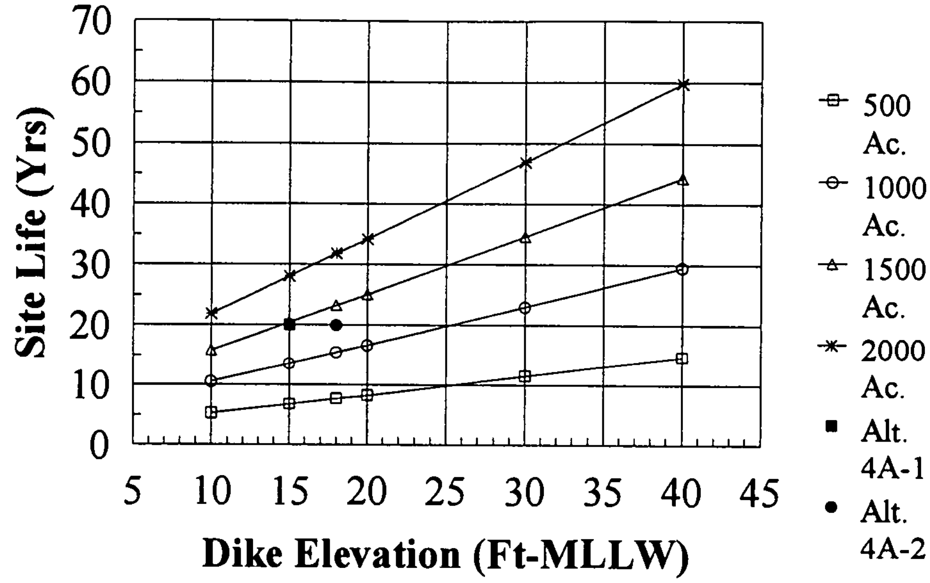

Figure 6-5a - Site Life vs Dike Elevation - Site 4A

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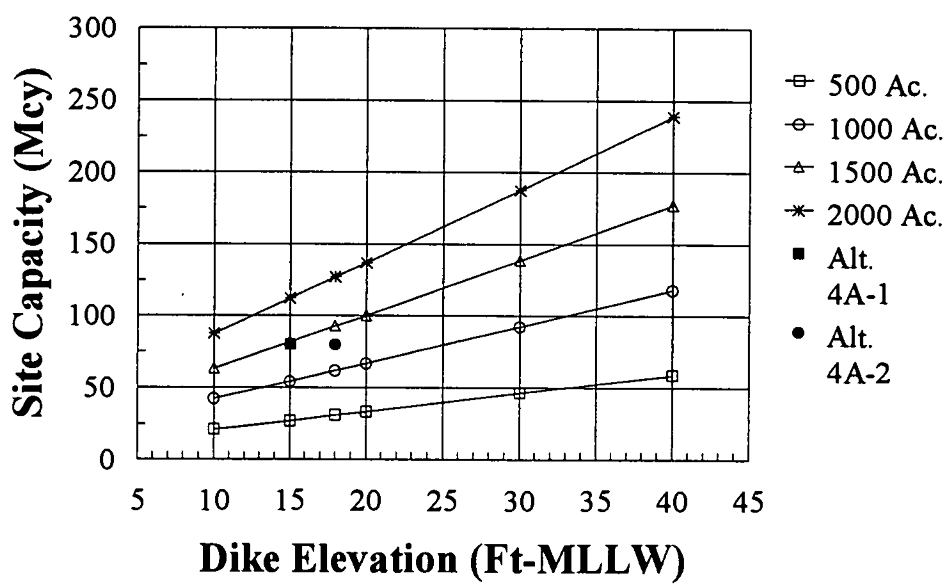

Figure 6-5b - Site Capacity vs Dike Elevation - Site 4A

GAHAGAN & BRYANT ASSOCIATES, INC.

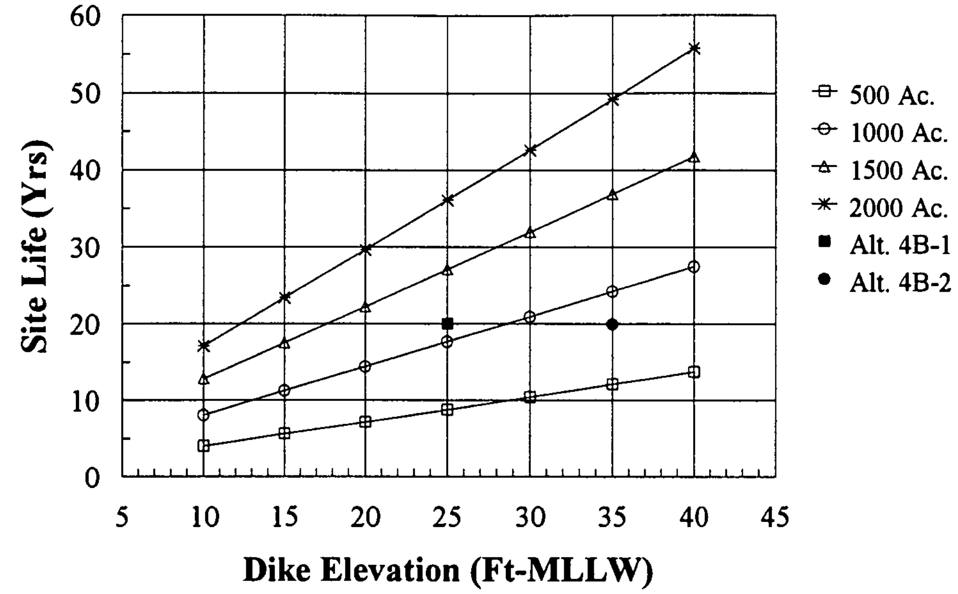

Figure 6-6a - Site Life vs Dike Elevation - Site 4B

GAHAGAN & BRYANT ASSOCIATES, INC.

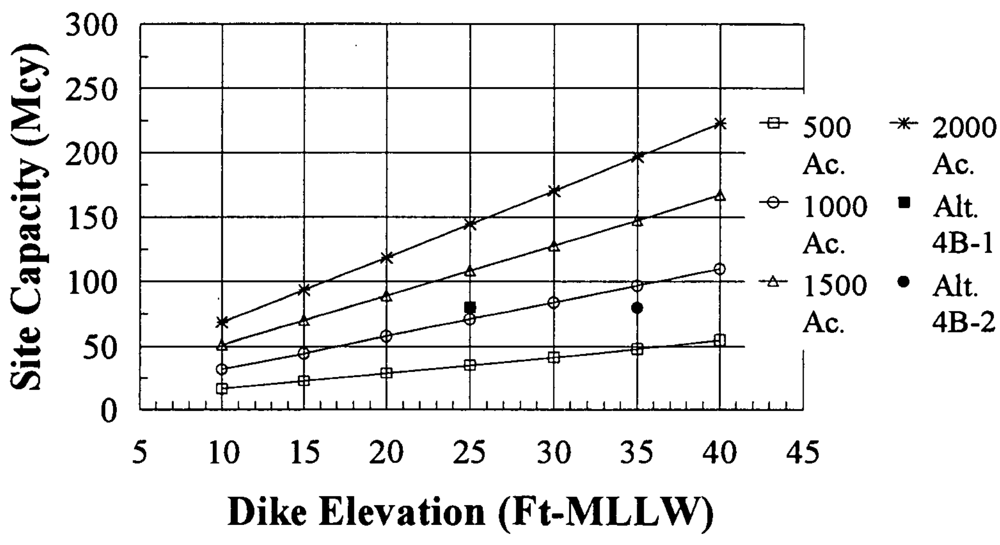

Figure 6-6b - Site Capacity vs Dike Elevation - Site 4B

GAHAGAN & BRYANT ASSOCIATES, INC.

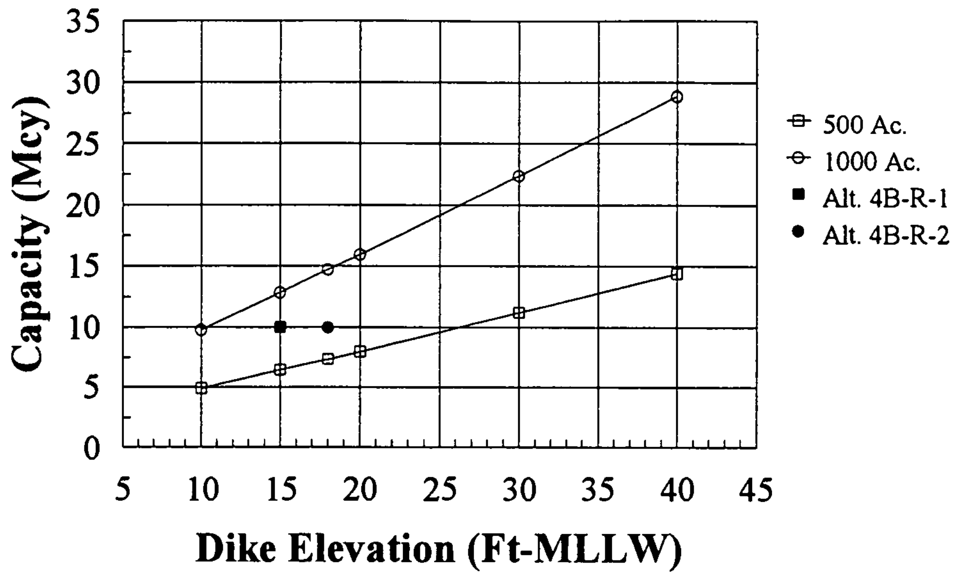

Figure 6-7a -Site Life Elevation - Site 4B-R

GAHAGAN & BRYANT ASSOCIATES, INC.

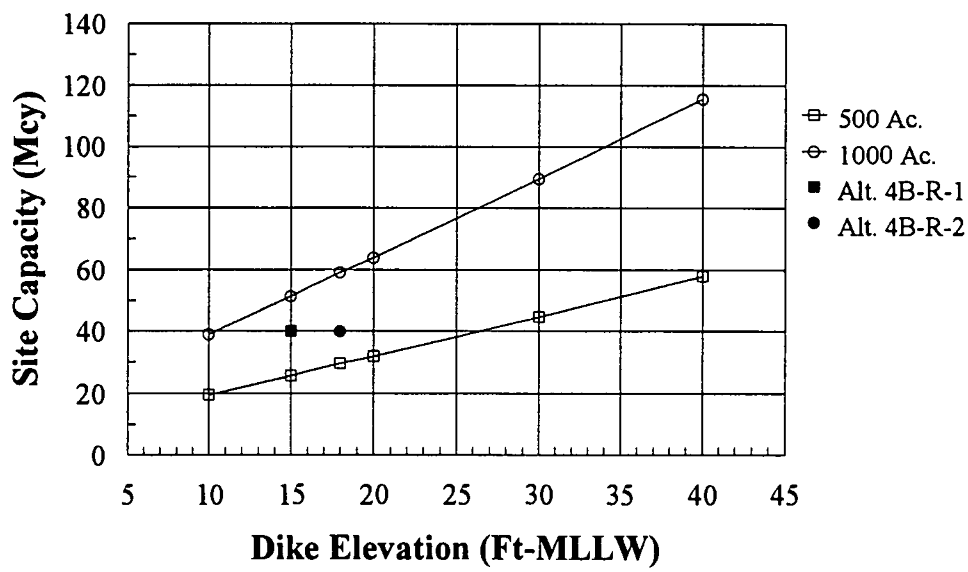

Figure 6-7b -Site Capacity vs Dike Elevation - Site 4B-R

GAHAGAN & BRYANT ASSOCIATES, INC.

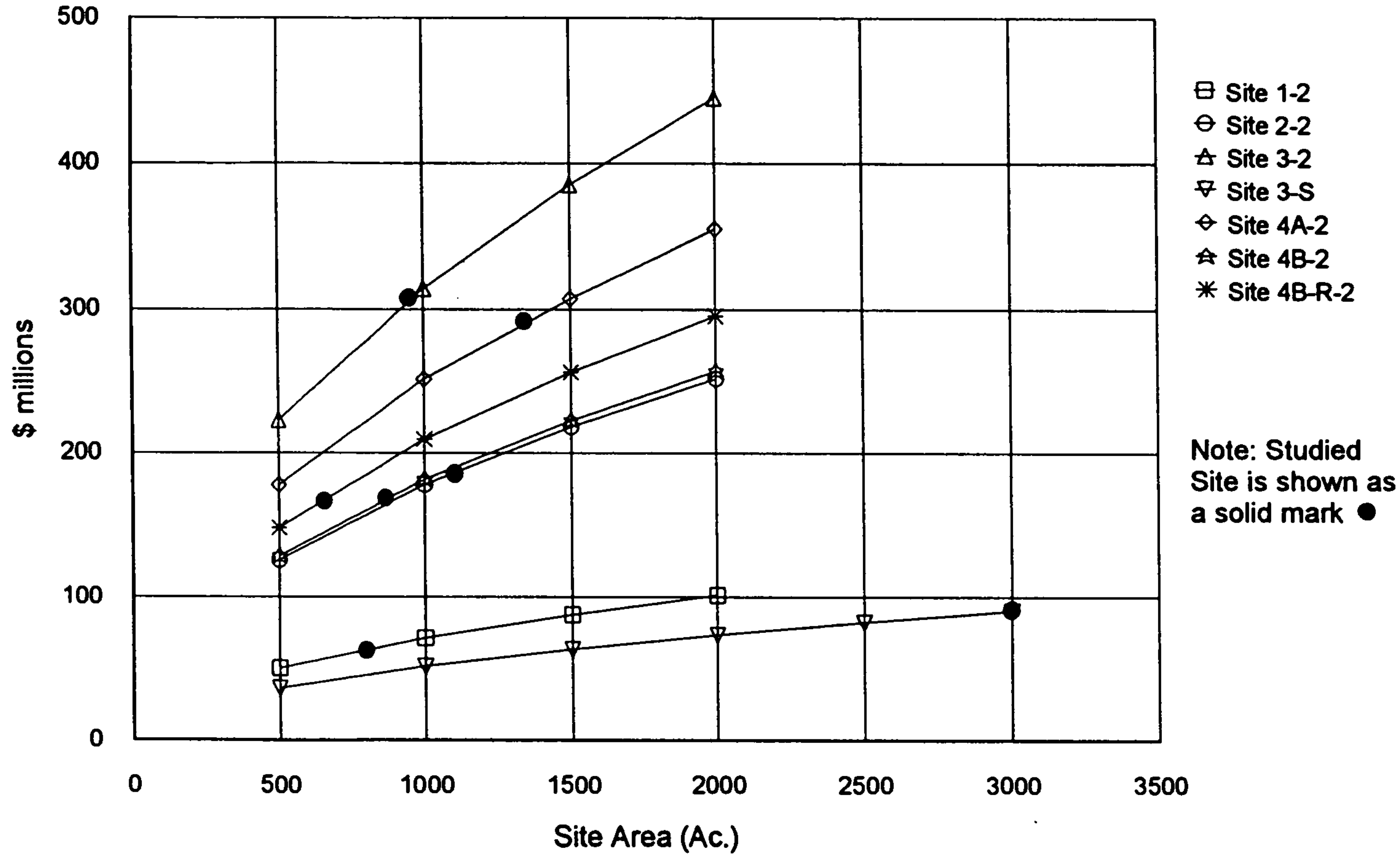

Figure 6-8 Initial Construction Costs vs. Site Area

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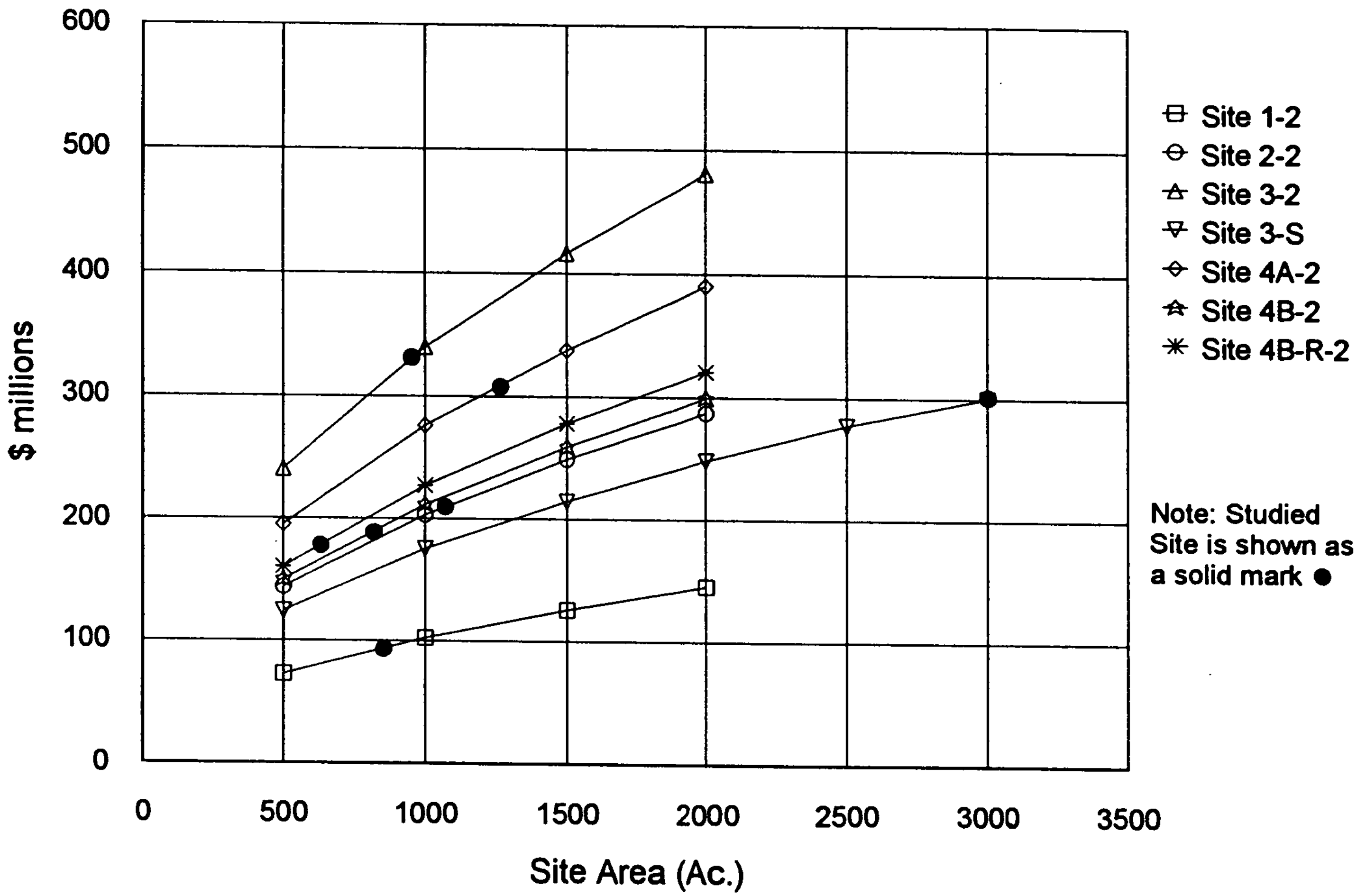

Figure 6-9 Site Development Costs vs. Site Area

GAHAGAN & BRYANT ASSOCIATES, INC.

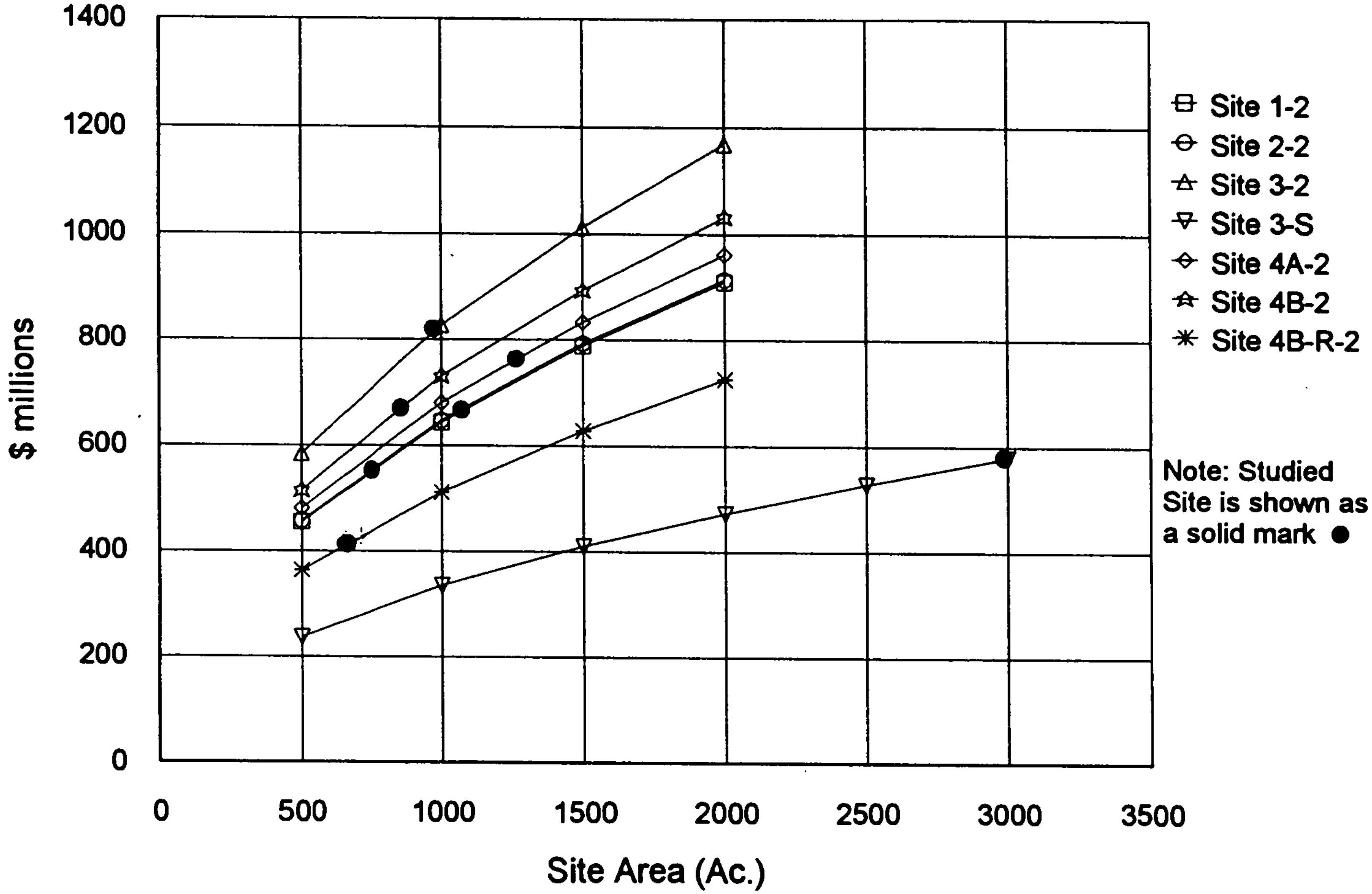

Figure 6-10 Total Costs vs. Site Area

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7.0 ENVIRONMENTAL INVESTIGATION

The environmental investigation for this prefeasibility study was conducted by EA Engineering, Science, and Technology. This chapter contains information in Section 7.1 regarding the methodology used to gather information and collect data, while Section 7.2 provides a description of the existing condition of natural resources in the study area. A discussion of social / public welfare resources in the study area is provided in Section 7.3 while Section 7.4 provides the rationale used to evaluate environmental parameters and the numerical results of the environmental rating. Section 7.5 discusses the summary of the environmental findings of the environmental investigation.

7.1 Methodology

The specific data collection techniques utilized for the environmental investigation in the prefeasibility study are detailed in the following sections. Basic site evaluation techniques are also described within this chapter. The specifics of site numerical evaluation are discussed in Section 7.4.

7.1.1 Site Information

Information for the potential placement sites was gathered from a variety of sources described below. The predominant data types were existing datasets, databases, and reports, as described below. Datasets included non-electronic data provided by resource agencies or working group participants. Databases included monitoring programs' data in electronic format. A limited amount of new field data were obtained by EA and other contractors working on this project. Most of the new data acquisition focused upon obtaining enough information on each site to facilitate the evaluation of each site's general habitat characteristics and quality. Because there was a limited amount of site-specific information for some of the study sites, the new information improved the ability of the project team to determine the suitability of development.

7.1.1.1 Existing Datasets and Reports

Existing data were obtained from a number of sources. Much of the pertinent existing information was gathered previously by MES for other DNPOP activities. MES provided several summary reports and much of the background information from these reports. Much of the background information was originally obtained from various resource agencies in the region and cataloged by MES. Considerable information was available for the Pooles Island area as a result of environmental studies and monitoring coordinated for MPA and Philadelphia District, USACE (PCOE) by MES. In addition, EA contacted the agencies and private concerns listed below. For several of the agencies, multiple divisions were contacted.

- Maryland Department of the Environment (MDE)
  Technical and Regulatory Services Administration (TARSA)

- Maryland Department of Natural Resources (MDNR)
  (Oxford Lab, Tidewater Fisheries, Heritage Division)

- National Marine Fisheries Service (NMFS)
  (Oxford Lab and Chesapeake Bay Program [CBP], Annapolis office)

- U.S. Fish and Wildlife Service (USFWS)
  (Chesapeake Bay Field Office)

- USACE Baltimore District
  (Planning and Operations)

- USACE Philadelphia District
  (Planning and Operations)

- Maryland State Historic Preservation Office (SHPO)
  (Maritime Division)

- Aberdeen Proving Grounds (APG)

- Versar, Inc.

- Maryland Charter Boat Association (MCBA)

- Baltimore Watermen's Association (BWA)

- Maryland Watermen's Association (MWA)

- Maryland Environmental Services (MES)

- Maryland Geological Survey (MGS) of MDNR

Some of these contacts provided written reports or electronic data. Most provided verbal information. For those that were contacted by letter, a copy of the letter is provided in EA 1997. Very few written responses were obtained. Response letters and other written correspondence are also provided in EA 1997.

7.1.1.2 GIS Database

Some of the general resource information and data obtained for this effort came directly from the MDE Geographical Information System Database (GISD). In this way, MDE was able to provide site-specific graphical information that was subset to include only the areas of interest. The database was invaluable for information on several of the resource types of concern (e.g., distribution of oyster bars, state water sampling sites, etc.).

7.1.1.3 Field Surveys

Field surveys were conducted to provide screening-level information for benthic communities, physical properties of the sediment, and sediment chemistry in each of the proposed island placement areas. Water quality was measured in conjunction with benthic sampling.

Station Locations

Five stations in each of the proposed island placement sites were sampled for baseline benthos and sediment quality data. Station locations were determined based on maps of existing bottom contours and substrate types and were chosen to ensure sampling of all available habitat types in each proposed area. Station locations with latitude and longitude coordinates are provided in EA 1997.

At each station, the boat was anchored, and latitude and longitude were determined using a Trimble® differential Global Positioning System (GPS).

Water Quality

In-situ water quality characteristics were measured using a YSI® Model 3800 (field) Water Quality Analyzer. Water temperature, pH, dissolved oxygen, salinity, and turbidity were measured for bottom, mid-depth, and surface water. If bottom measurements indicated the presence of a pycnocline, additional water column measurements were conducted at several depths. Water clarity was measured using a secchi disk.

Benthic Macroinvertebrates

A baseline benthic inventory was conducted at 5 stations in each of the proposed placement areas (a total of 25 samples). The community was sampled using a 9 in. by 9 in. Ponar grab sampler that samples an area of $0.05m^2$. One sample was collected at each station. These data were used to provide a relative measure of the community composition and an indication of homogeneity or non-homogeneity in the region. These data do not provide a measure of variability at each station.

General observations of sediment type, color, composition, and surface biology were noted for each grab. Samples were washed in the field through a Wildco® wash bucket with a number 30 mesh (600 micron) screen in order to remove fine sediment particles. The samples were then placed in labeled 1-L polyethylene jars and preserved in 10 percent buffered formalin with rose bengal stain. All samples were transported to EA's biological laboratory, logged for sample tracking, then hand delivered to Cove Corporation in Lusby, Maryland for sorting and identification. At Cove, samples were sorted and identified to species (or to the lowest practical taxon). Oligochaetes and chironomids were not identified to species due to time constraints and the screening-level nature of the study. Ash-free dry weight biomass was determined for major taxonomic groups using methods outlined in EA 1997.

Sediment Quality—Physical and Chemical Analyses

At each benthic station, a second grab sample was collected for surficial material grain size, moisture content, and organics analysis. In addition, sediment from two of the five stations in each area was collected for sediment chemistry analyses (a total of 10 samples). All sediment samples were placed on ice and hand delivered to EA Laboratories in Sparks, Maryland. Grain size, moisture content, and organics determination were conducted by E2Si located in Baltimore, Maryland. Chemical analyses for trace metals were conducted by EA Laboratories. A list of analytes and laboratory methodologies is provided in EA 1997.

Pooles Island Reconnaissance

Four EA scientists participated in a 1-day visit to Pooles Island, under escort of the APG professional staff, to qualitatively survey the upland habitat and near shore resources on the island. Near-shore substrate composition and historical resources located on the island were observed and documented. Inventory listings were created for flora and fauna observed in the upland and wetland habitats. In addition, APG provided site-specific documentation for terrestrial, aquatic, and cultural resources associated with the island. Notes from this survey are included in EA 1997.

7.1.1.4 Other Sources

In addition to the sources outlined in this section, EA obtained a limited amount of information from the Internet, specifically the Chesapeake Bay Program site and linked sites. The other contractors that were conducting geotechnical surveys of the proposed sites also provided sediment composition and hydrodynamic information to EA for incorporation into this section. Note that hydrodynamic modeling was not complete at the time this section was prepared. Since that time, modeling has been completed but a re-evaluation of the environmental effects will not be made until 3-D modeling is completed.

7.1.2 Site Rating

This section of the report establishes the environmental parameters that were included in the rating and the rationale for the selection of these parameters. The general method of assigning scoring to each of the environmental factors is also described below. The specific criteria used to assign an evaluation for each parameter are included in Section 7.4 where the numerical rating for each parameter at each site are detailed.

7.1.2.1 Resource Scoring Indices

Eighteen parameters were used to evaluate the environmental suitability of the five proposed sites. A brief description of each resource category is presented below. A complete list of these parameters is provided in Table 7-1 along with the factors considered for each parameter.

Water Quality

Water quality is an important environmental parameter that can significantly influence the type of flora and fauna present at any particular site. A suite of water quality parameters were described for each site, three of which initially were considered for evaluation: dissolved oxygen, salinity, and total suspended solids. These factors have demonstrated influences on distributions of aquatic organisms of the Bay. According to known habitat requirements for living Chesapeake Bay resources (Funderburk et al. 1991), naturally occurring TSS concentrations in the upper Bay do not exceed concentrations that would be detrimental to larval, juvenile, or adult lifestages of commercially important species. Salinity has been considered as a separate parameter because modeling had to be done for the evaluation. Dissolved oxygen, therefore, was the only parameter actually used for this analysis. In addition, potential changes in water quality and effluent dispersion from Back River and HMI resulting from disruption to hypothesized gyre circulation (Wang 1992) were considered relative to each site.

Salinity

Salinity is among the most significant influences on the distribution of aquatic organisms in estuaries. Preference for and tolerance of salinity dictates the types of organisms that can live in various areas, and therefore, dictates the structure of the aquatic community. Alterations in regional salinity ranges could influence the aquatic community structure significantly. Additionally, the saltier waters from the ocean travel up the Bay in a wedge near the bottom through the areas of deepest water. This salt wedge enables organisms from saltier areas of the Bay to disperse into fresher water feeding and nursery areas. The potential for significant alterations to regional salinity or the salt wedge were evaluated at each site.

Hydrodynamic Effects (Physical Effects)

Wind-driven currents and tidal currents affect the distribution of biological organisms and nutrients, sedimentation patterns, and rates of erosion. Large unnatural structures can alter the flow velocity to the point that significant changes in sedimentation, erosion, and potentially the distribution of biological organisms could occur. Hydrodynamic two-dimensional modeling was conducted by Moffatt and Nichol, examining the hydrodynamic effects of island placement at each site. Site-specific variations of facility size and orientation were evaluated for hydrodynamic properties. Results of this preliminary hydrodynamic modeling were summarized, evaluated, and incorporated into the environmental analysis. More comprehensive hydrodynamic modeling, including use of a three-dimensional model, will be needed at the feasibility stage of the investigation to fully characterize prospective hydrodynamic effects on the ambient environment of the selected sites. For this evaluation, the physical effects of hydrodynamics (erosion/sedimentation and increased currents in shallow areas) were considered separately. Potential effects on larval fish distributions and current effects to navigation are considered separately.

Sediment Quality

Sediment quality, particularly physical and chemical characteristics, influences biological communities. The physical and chemical composition of the benthic environment within the proposed placement sites provides important information that will be used to characterize the relative condition of the site, the quality of habitat available to higher trophic levels at the site (such as fish), and the suitability of the site for construction. Sediment quality was evaluated for each of the proposed island placement sites based on data for trace metals concentrations. These data were compared to concentrations that are known to potentially cause adverse toxic effects to aquatic biota. This analysis was conducted to differentiate site conditions on a screening level based upon potential stressors to aquatic biota regardless of origin (natural or anthropogenic). Physical attributes of the sediment in relation to foundation stability and potential borrow areas were evaluated by E2Si (1997) and included in the economic evaluation of the sites (GBA 1997).

Benthic Community and Habitat

Benthic communities are an important component of the Chesapeake Bay ecosystem. Benthic organisms provide a trophic link from phytoplankton to higher trophic levels, serve as a food source for commercially important fish and shellfish, and play a role in nutrient cycling. Salinity and substrate are natural characteristics that influence the structure of the benthic community. Sediment composition was evaluated based on site-specific data collected by Maryland Geological Survey, E2Si, and EA. Benthic assemblages are often used as indicators of environmental or anthropogenic stress in aquatic systems. An estuarine Benthic Index of Biotic Integrity (B-IBI) has recently been developed for Chesapeake Bay benthic communities (Weisberg et al. 1997). The B-IBI is salinity- and substrate-specific and evaluates attributes of the benthic community, such as diversity, abundance, biomass, proportions of pollution-sensitive and pollution-tolerant species, and trophic feeding guilds to determine the relative condition (or environmental health) of the site.

Recreational Fishery

The recreational fishery in the Chesapeake Bay is among one of the most valued resources in the SOM. The Bay supports a large number of fish and a high diversity of species sought by recreational anglers. Some areas of the Bay are favored by charter boat captains and others by individual recreational anglers. The potential for each area to be utilized by recreational species and the actual use of each area by recreational anglers was evaluated in the context of the regional fishery.

Commercial Fish and Shellfish

Fish species used for the screening included *Morone americana* (white perch), *Morone saxatilis* (striped bass), herring (*Alosa*) species *Alosa aestivalis* (blueback herring), *Alosa mediocris* (hickory shad), *Alosa sapidissima* (American shad) and various species in the family *Sciaenidae* (spot, croaker, etc.). Shellfish considered included *Callinectes sapidus* (blue crab), *Crassostrea virginica* (oysters), and *Mya arenaria* (soft clams) because all of these species are harvested in the upper Bay (Larry Simms, MWA, October 1997). These species were selected because of their historical commercial importance, and, in some cases, because of population declines which have caused the imposition of state or federal restrictions on the taking of these species. Each of these species uses the upper Bay during at least one lifestage and all of these species are typically used in evaluating the value of the fishery resources of the Chesapeake Bay (MES 1997b). Commercial shellfish and crabbing areas are limited (by regulations) within the upper Bay. Each site was evaluated based upon commercial shellfish and crabbing areas within or immediately adjacent to the site.

Finfish Spawning

Portions of the upper Bay are known to be crucial spawning and/or nursery areas for a large number of fish species that occur throughout the Chesapeake Bay. This is particularly the case in shallow water areas, or areas that have significant amounts of underwater structure or other cover or that lie within critical salinities. Because finfish spawning areas have received legislative protection, these spawning areas were considered separately from other fish resource and habitat issues. Anadromous species, such as striped bass, American shad, blueback herring, and alewives migrate up-Bay to freshwater and oligohaline areas to spawn. The same areas are utilized by a variety of species resident to those salinities for spawning (including such important species as White Perch). These fresh or lightly brackish areas are also known to support the early lifestages of several important fish species that spawn in much higher salinities.

Larval Transport

Discharge from the Susquehanna River and other upper Bay rivers transports the early lifestages of species that are spawned in the rivers to feeding and nursery areas further south (down the Bay). In contrast, the salt wedge and tidal currents help to transport young of fish that are spawned in saltier areas to feeding areas in the upper Bay. Significant alterations to the currents that influence these larval transport mechanisms could have detrimental effects on fish populations. Residence time modeling was conducted to attempt to predict significant alterations in water mass distribution and suspended particulate (e.g., larval fish) transport. The extent to which larval transport could be influenced by alterations in hydrodynamics was examined at each site, to the extent possible.

SAV and Shallow Water Habitat

SAV has historically declined over most of the upper Bay. These declines are thought to be due, in part, to high turbidity and nutrient loading. *Myriophyllum spicatum* (Eurasian water milfoil), *Hydrilla verticillata* (hydrilla), and *Potamogeton perfoliatus* (clasping weed pondweed) are currently among the most common species of SAV in the Chesapeake Bay.

The Chesapeake Bay Program has issued guidance for protecting SAV in the Chesapeake Bay and its tributaries (CBP 1995). The Chesapeake Bay Program's Executive Council established a SAV Policy in 1989 and committed to an implementation plan in 1990, to achieve the goal of "a net gain in SAV distribution, abundance, and species diversity in the Chesapeake Bay and its tidal tributaries" (CBP 1990). This policy is meant to protect SAV "from further losses due to increased degradation of water quality, physical damage to the plants, or disruption to the local sedimentary environment" (CBP 1995). The Chesapeake Bay Program developed a three-tiered framework of SAV restoration goals or targets:

Tier I: restoration or establishment of SAV in areas of historic (1971 - present) distribution

Tier II: restoration or establishment of SAV in potential habitat to a depth of one meter

Tier III:restoration or establishment of SAV in potential habitat to a depth of two meters

Unvegetated potential habitat areas are protected by the Chesapeake Bay Program's three-tiered SAV restoration goals.

Several state and federal agencies have SAV regulations and policies; however, many of these regulations and policies apply specifically to SAV and not necessarily to potential, unvegetated SAV habitat (CBP 1995). In order for the goals of the Chesapeake Bay Program to be attained, the policies and regulations of these agencies must be considered in all shallow water areas providing SAV habitat.

Recommended SAV protection guidance by the Chesapeake Bay Program includes avoiding dredging activities in Tier I, Tier II, and Tier III areas. Additional guidance includes avoiding dredging, filling, or construction activities that create additional turbidity in or near SAV beds during the growing season; establishing buffers around SAV beds to minimize direct and indirect impacts on SAV during activities that significantly increase turbidity; preserving natural shorelines and stabilizing shorelines when needed; and educating the public about the negative effects of recreational and commercial boating on SAV and ways to avoid or reduce these effects (CBP 1995).

Maps of SAV distribution in recent years were examined to determine if SAV has been present within the proposed sites. Additionally, shallow water habitat is valuable for many ecological reasons, even in the absence of SAV. Both were considered together in evaluating this parameter.

Waterfowl Use

The Chesapeake Bay is utilized as breeding and feeding habitat for many species of waterfowl. Shallows are used for feeding and /or rearing of young. Deeper areas are also important for resting and staging (or flocking). The Bay is used by both migratory fowl and residents, and serves as a significant staging area for some species along the Atlantic flyway.

Tidal Wetlands

This category is limited to the Pooles Island area where the possibility of affecting wetlands exists. Sites containing wetlands were considered less suitable for the construction of a dredged material placement site. In addition, sites that may cause erosional impacts to this resource were also considered less suitable for construction.

Terrestrial Habitat and Wildlife

This category is limited to the Pooles Island area where the possibility of impacting terrestrial habitat and wildlife exists. Only sites that will potentially abut the island were considered as potential impacts to these resources. In addition, sites that may cause erosional impacts to this resource were also considered less suitable for construction.

Protected Species (RTE)

The distribution of both state and federally protected (i.e., Rare, Threatened, and Endangered [RTE]) species relative to the five potential placement sites was determined through correspondence with both state and federal resource agencies. The presence or probable presence of a protected species was considered to be a negative relative to the development potential of a dredged material placement site. The occurrence of shortnose sturgeon and the proximity to bald eagle nesting areas were evaluated for each site.

Recreational Value

The Upper Chesapeake Bay is heavily used as a recreational area. The diverse recreational activities include bird watching, boating, swimming, fishing, etc. For this evaluation, fishing is already evaluated elsewhere, so it was not included with this parameter.

Historic Resources

Information on the potential for archaeological and historic sites was requested from the State Historic Preservation Office for each of the five proposed sites. The potential presence of shipwrecks and other historical features as well as any archaeological resources known to occur (from existing reports) were considered in the evaluation.

Aesthetics and Noise

Aesthetics and noise impacts from the construction and operation of a dredged material placement facility can be a negative impact if the site is near a population center or heavily used area. If a site is located within approximately 0.5 mi of a population center, it was considered to have the potential to have a negative impact on aesthetics and noise.

Fossil Shell Mining

In portions of the Upper Chesapeake Bay, fossil oyster shell beds are mined for MDNR to provide culch for oyster replenishment in the middle and lower portions of the Bay. Fossil shell mining is viewed as an important resource for the continued production of oysters from the Bay.

CERCLA and Unexploded Ordnance (UXO)

As part of its mission, APG currently tests, and has historically tested, weapons in portions of the Chesapeake Bay around Pooles Island. This included the firing of live rounds southeastward of Pooles Island to about 10,000 yd outside of the APG boundary. Some stray shells are known to have exceeded this distance. The APG Controlled Areas and other portions of the upper Bay are believed by APG to contain shells that did not explode during testing. The presence of unexploded ordnance (UXO) could significantly complicate the construction of a containment facility. Also, any site that is known to have the potential for existing pollutants or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) liabilities would be a poor choice for a dredged material placement facility if construction would potentially remobilize contaminants into the environment. With respect to UXO, there is no approved remediation policy. There is also no specific federal policy regarding the liability of potential responsible parties. These are institutional issues which would need to be addressed in addition to the potential environmental and safety implications associated with UXO.

Navigation

Safe and effective navigation is essential to the vitality of the Port of Baltimore and the commerce of the region. Due to the large volume of barge and container traffic in the upper Bay, the potential effects of the proposed sites on local navigation were evaluated. Sites that lie partially or wholly within navigation channels could be considered hazards to navigation. Additionally, sites adjacent to channels could have an impact on navigation due to increased currents from altered hydrodynamics. A structure that may hinder navigation can also pose a potential environmental threat from potential ship collisions and groundings.

7.1.2.2 Numerical Evaluation

The framework for site evaluation generally follows what was developed for use in the Port of Baltimore Dredged Material Master Plan (MPA Draft 1989). The draft Master Plan included methods to evaluate sites based upon either the presence/absence or the quality of a particular resource. The initial scoring in the draft Master Plan simply involved using a "plus" (+) for sites where minimum impact was expected, or a "minus" (-) where impact was expected to be substantial. The base evaluations were multiplied by a resource-specific weighting factor in an attempt to reflect the relative importance of the resource on a Bay-wide basis. The final (weighted) evaluations were added up for each site to provide a numeric rating.

There are numerous methods that can be applied to this evaluation, but because the data available for this prefeasibility study were largely limited to existing data and a similar quantity and quality of information was not available for each site, a simple plus (+1) or minus (-1) was used to rate each site for each of the environmental parameters listed above. This approach is similar to that used in the Master Plan. In this context, a positive evaluation (+1) indicates that for a particular environmental resource, the construction of the dredged material placement facility on that site would be preferred over sites that have a negative (-1) affect for that resource. A value of +1 was used if, for example, a resource was already degraded or no impact was expected. A negative value (-1) was assigned where a particular resource was of high quality. In cases where insufficient information was available to make a determination (ambiguous information), or the resource was somewhat affected and little further impact was expected, the site received a zero (0).

The Master Plan included a more limited number of parameters than was identified for this study, so no weighting factors existed for some of the resources of concern. Because the practice of weighting parameters is subjective and is best accomplished by the consensus of a number of resource professionals, no weighted analysis was initially conducted for the sites. In direct response to Working Group comments, the concept of using weighting factors was reconsidered. Base evaluations were weighted to determine if this would significantly influence the final site environmental ratings. To the extent practicable, the weights established in the Master Plan were used for continuity with that multidisciplinary effort. Some weighting factors were modified from the original values in the Master Plan based upon knowledge gained since 1989 when the original factors were developed. Where weighting factors were not available for a particular parameter or not appropriate in view of available information, a weight for a closely related parameter was adapted, or the EA project team assigned a weight based upon best professional judgement with input from MES regarding the Bay Enhancement Phase II deliberations and environmental monitoring and documentation performed by MES for the MPA and PCOE, and advice from the Upper Bay Island Placement Sites Working Group.

7.1.3 Non-Rated Considerations

During the rating and evaluation process it became apparent there were several site development considerations that were not appropriate to include with the natural resource or human environment evaluations. Although important from a planning perspective, some development considerations can not be judged against each other in a numeric (matrix) fashion. One such consideration was institutional constraints such as state laws and property ownership. Although these constraints are an integral part of site evaluation, assigning a numeric evaluation in terms of the value on a regional basis (as the other factors are rated) was not plausible. The potential for beneficial uses at a site was excluded from the matrix-type (numeric) evaluation due to the difficulty in assigning consistent numeric values (that would be agreeable to all stake holders) to the various types of beneficial uses. The non-rated considerations are detailed in the following section.

7.1.3.1 State Law/Institutional Constraints/Property Ownership

According to the federal Coastal Zone Management Act (CZMA) Section 307 16 U.S.C. 1456, a federal agency engaging in an activity such as dredging and filling may be exempt from a state's requirements for a permit, but is still bound by the CZMA to be consistent with the enforceable provisions of the state's program (MES 1994).

Pooles Island is part of the APG (MES 1994). In 1976, a case came before the federal district court in Baltimore which found that the property of APG included all subaqueous sites within the boundary (MES 1994). This ownership and jurisdiction is confirmed by Article 96, 36, Maryland Annotated Code (MES 1994). Pooles Island is within APG boundaries and lies totally inside of Harford County (MES 1994).

One result of federal ownership of APG is that many activities on the property are technically exempt from state and local laws and regulations, including the Chesapeake Bay Critical Site Protection Program, State Nontidal Wetlands Protection Act, Harford County's Zoning Ordinance, etc. (MES 1994). The facility must comply with federal laws and regulations (MES 1994); however, APG has developed agreements with state and local government agencies regarding natural resources conservation. Locations of the proposed island placement sites in relation to the APG boundary are included in Figures 3-1 and 3-5.

Sites 1, 2, and 3/3S lie wholly outside of the APG Controlled Area. Sites Nos. 4A and 4B include portions that lie within the APG Controlled Area. Only a small portion of Site 4A is within the APG boundary, whereas greater than 50 percent of Site 4B would lie within the boundary. Site 4B-R was chosen and positioned to lie wholly outside of the APG boundary.

7.1.3.2 Potential for Beneficial Use

Beneficial use options that have been considered for dredged material include: marsh restoration and creation, shoreline stabilization and protection, island restoration, enhancement of fisheries habitat, constructed reefs, and various alternative uses such as recycling and use of dredged material as a construction aggregate (MES 1997a, Blama 1997, Spaur et al. 1997). Many beneficial use options proposed for the upper Bay have not, however, gained broad-based interagency or public support (MES 1997a, Young and Hamons 1997).

At Sites 1 and 2, the principle potential beneficial use, at this time, would be upland habitat (island) creation, which is not among the preferred beneficial uses of some resource agencies (John Gill, USFWS, October 1997). Although some construction options may include enhancements of fisheries habitat, these would have to be determined during the feasibility and design phases.

At Site 3, the principal beneficial use would be island creation; however, one construction alternative for this site that is already being considered is a submerged island site (3S) that is planned as a significant enhancement of fisheries habitat. For the Site 3S option, the dikes would only be raised to a height of -10 or -12 ft (MLLW) and when filled, the site would be a shelf above the summer pycnocline. The shelf could then be covered with rock or fossil shell (culch) to provide physical habitat/cover for fish and shellfish.

Pooles Island was among five sites identified by a DNPOP inter-organizational working group with concepts for creating or restoring intertidal marshes (MES 1997a). Site 4A is currently proposed to be detached from Pooles Island, so the principal beneficial use would be as island habitat. If Site 4B is abutted to Pooles Island it has the highest potential for creation of intertidal marshes. The principle beneficial use of the detached (4B-R) alignment would be for island habitat.

7.2 Natural Resources

7.2.1 Water Quality

Existing Water Quality Information

Maryland's Chesapeake Bay Water Quality Monitoring Program has monitored water quality throughout the Bay since 1984. Three Chesapeake Bay Program Water Quality Monitoring (CBPWQM) stations in the upper Bay are located in the vicinity of the proposed project site, MCB2.2, MCB3.1, and MCB3.2 (Figure 7-1). These data sets provide the most complete, comparable, and representative water quality data for the five proposed placement sites. Water quality at MCB3.1 and MCB3.2 is expected to be most similar and comparable to conditions at Site 1. Water quality at MCB3.2 is expected to be most representative of Sites 2 and 3. A combination of conditions at MCB2.2 and MCB3.1 is expected to be most comparable to conditions at Sites 4A and 4B due to the influence of freshwater flows from the western shore. Overall, depths at the water quality monitoring stations are comparable to depths at the proposed placement sites, with the exception of Sites 1 and 4B (which are shallower). Yearly seasonal trends for important physical and chemical measurements are discussed in the following section and are evaluated for each of the five sites.

Salinity

Salinity in the Upper Bay varies spatially and temporally. Freshwater inflow from the upper Bay tributaries and the Susquehanna River influences the seasonal salinity regimes. Generally, salinity in the upper Bay region is classified as oligohaline (0.5-5 ppt), low mesohaline (5-10 ppt), or high mesohaline (10-18 ppt). Lower salinities occur in the spring, and higher salinities are prevalent in the summer/fall. Differences in surface and bottom salinity are variable depending upon water depth and freshwater inputs. Shallower regions of the upper Bay are generally well mixed and uniform, and deeper regions generally exhibit a fresher surface layer and a saltier bottom layer (or wedge) of water.

Dissolved Oxygen

Dissolved Oxygen (DO) is critical to the survival of biological organisms. DO values of >5 mg/L are necessary to sustain fish and shellfish species (Funderburk et al. 1991). Sites with DO concentrations < 2 mg/L are categorized as hypoxic. Hypoxic conditions are influenced by freshwater flows in the spring and by vertical stratification in the water column during the summer months. Additionally, oxygen depletion can result from eutrophication (an over-abundance of nutrients). Large phytoplankton blooms, fueled by nutrients, die-off and decompose, thus depleting DO in the surrounding waters. The most frequent occurrences of low DO concentrations occur in the summer months in the deep, central areas of the Bay.

Turbidity and Water Clarity

Turbidity in the upper Bay is elevated during the majority of the year due to the transport of suspended organic materials by the upper Bay tributaries and due to wind induced mixing (USACE—Philadelphia 1996). The region of the upper Bay which includes Pooles Island is known as the estuarine maximum turbidity zone, and turbidity increases with depth (Schubel 1968). In the zone of maximum turbidity, where freshwater and saltwater fronts meet, turbidity and suspended sediment concentrations are greater than concentrations found in source waters upstream and receiving waters downstream in the estuary (Schubel 1968). Bottom sediments in the area are resuspended by tidal scour and are trapped by the net non-tidal circulation (Schubel and Hirschberg 1980 cited by MES 1997a). The resuspension of sediment particles increases turbidity and reduces water clarity in the region. Turbidities in the region, measured as total suspended solids (TSS) or nephelometric turbidity units (NTU), are generally greater than those found upstream in the tributaries or farther downstream in the estuary (Schubel 1968).

Nutrients

In general, phytoplankton and chlorophyll levels are reduced in the upper Bay compared to areas further south due to higher turbidity in the region (Ruddy 1990). Ammonia is the preferred nitrogen source for phytoplankton, and is released by anoxic bottom sediments in the deep central areas of the Bay. Ammonium peaks typically occur during the summer in bottom water samples. Nitrite, nitrate, and total nitrogen concentrations are related to river flows, and are typically elevated in surface waters during spring in upper regions of the Bay (March through May) (CBPWQM 1997). Silica concentrations are also generally higher in the upper Bay due to contributions from freshwater inputs (CBPWQM 1997).

Water Quality at the Proposed Sites

Site 1

The majority of water quality characteristics for Site 1 are expected to be comparable to a combination of conditions at MCB3.1 and MCB3.2. Salinities in this region have historically ranged from 0 ppt to 13 ppt for surface waters and from 0 ppt to 17 ppt for bottom waters throughout the year (CBP data from 1992-1996). Highest salinities occur during late summer and early fall. According to CBP data, bottom waters in this region typically exhibit low DO during the late summer and early fall (<1 mg/l), and surface waters remain above 5 mg/l (EA 1997). Although hypoxic conditions have historically been recorded at MCB3.1 and MCB3.2, bottom DO measurements at Site 1 during the summer of 1997 did not identify hypoxic conditions (EA 1997). MCB3.1 is located east of Site 1 in deeper water (11-13 m). Although hypoxic conditions have been recorded at MCB3.1, the Site 1 region may not experience severe summer anoxia due to its location in shallower water (2.9 m to 4.3 m). Secchi values recorded during the summer 1997 surveys fall within the normal ranges expected for this season of the year (EA 1997). Bottom TSS values historically reported at MCB3.1 have ranged from 6 mg/l to 233 mg/L, with a mean of 33.8 mg/L and values at MCB3.2 have ranged from 3 mg/L to 271 mg/L with a mean of 27 mg/L (1992-1996 data). Spring peaks are generally at or below the range that is protective of many aquatic species/lifestages that occur in the area (Funderbunk et al. 1991) (CBP data 1992-1996). Trends for nutrients in the region are provided in EA 1997.

Sites 2 and 3

Water quality characteristics for Sites 2 and 3 are expected to be similar to those reported for station MCB3.2. Surface salinities have historically ranged from 0 ppt to 14 ppt (1992–1996 data). Bottom salinities fall in the upper mesohaline (10–18 ppt) range throughout most of the year, with the exception of years with above normal precipitation (CBP data 1992-1996). Because MCB3.2 lies in the deeper, central area of the Bay, the water column exhibits vertical salinity stratification, with a distinct upper fresher layer and lower saltier layer. Sites 2 and 3 have the highest salinities of the five proposed placement sites. Bottom waters in these areas typically exhibit low DO during the summer and early fall (<1 mg/L), and surface waters remain above 5 mg/L (CBP data 1992-1996). Low DO was confirmed throughout Sites 2 and 3 during summer 1997 surveys (EA 1997). Historical secchi data indicate that water clarity in the region is typically reduced during the spring, and is greatest in the late summer and early fall (CBP data 1992-1996). Secchi values recorded during summer 1997 surveys fall within the normal ranges expected for this season of the year (EA 1997). Bottom TSS concentrations at MCB3.2 have historically ranged from 3 mg/L to 271 mg/L throughout the year, with a mean of 27 mg/L (1992–1996 data). Trends for nutrients in the region are provided in EA 1997. Typically, concentrations of ammonia are elevated in anoxic bottom waters in the deep central regions of the Bay and peak during the summer (CBPWQM 1997).

Sites 4A and 4B/4B-R

Conditions at Sites 4A and 4B/4B-R are more influenced by the freshwater flows from the northern tributaries than any of the other proposed sites. Water quality at these sites is expected to be most comparable to conditions at MCB2.2 and MCB3.1. Because these sites lie within the turbidity maximum zone of the upper Bay, the water column is generally well-mixed and uniform.

Water quality characteristics at Sites 4A and 4B/4B-R are primarily influenced by flows from the Susquehanna River. Site 4B/4B-R is also influenced by flows from the western shore Bush and Gunpowder Rivers. Because these sites are relatively shallow (compared to the other sites), the water column exhibits little stratification, and differences between surface and bottom salinity are minimal. These sites exhibit the lowest salinities of the five proposed placement sites. According to CBPWQM data, surface salinities are < 6 ppt (oligohaline) throughout most of the year, with the exception of late summer and early fall. Bottom salinity is generally <10 ppt, except during extremely dry years. Summer 1997 surveys confirmed that these stations exhibited the lowest salinities of the five proposed placement sites (EA 1997).

Dissolved oxygen at Sites 4A and 4B/4B-R is expected to decline slightly in bottom waters during the late summer and early fall, primarily due to warmer water temperature (CBP data 1992–1996). Although hypoxia has historically been reported at MCB3.1, data for MCB2.2 indicate that bottom DO only occasionally falls below 4 mg/L. Such results at MCB2.2 are not unusual due to the shallow and uniform nature of the water column in these regions. Because unconfined placement of dredged material has occurred in the region since 1965 (Halka and Panageotou 1992), water quality has been studied extensively in the vicinity of Site 4A. Historical and recent surveys indicate that placement of dredged material has not created anoxic conditions in the sediment or water column (MES 1997a; Boynton et al. 1994; Boynton et al. 1996). Summer 1997 surveys confirmed that the region encompassing Sites 4A and 4B/4B-R exhibited a uniform and well-oxygenated water column (EA 1997).

Historical secchi data indicate that water clarity in the region is typically reduced during the spring, and is greatest in the late summer and early fall (CBP data 1992-1996). Secchi values recorded during summer 1997 surveys fall within the normal ranges expected for this season of the year (EA 1997). Because Sites 4A and 4B/4B-R lie near Pooles Island which is located in the turbidity maximum zone for the upper Bay, reduced water clarity from suspended particulates is expected and is a natural occurrence in the area. Historical concentrations of bottom TSS (1992–1996) reported for MCB2.2 ranged from 8 mg/L to 288 mg/L, with a mean of 49.8 mg/L. Historical values for MCB3.1 ranged from 6 mg/L to 233 mg/L, with a mean of 33.8 mg/L. These sites exhibit the highest bottom turbidity of the five proposed placement sites (EA 1997). Summer 1997 surveys reported the highest *in-situ* bottom turbidities at Site 4A, ranging from 8–24 NTU (TSS concentration not measured).

Nutrients in the upper Bay are influenced by flows from the Susquehanna River (CBP 1994). Nutrient cycling from water column to sediments and back to water column during phytoplankton blooms typically occur in spring and fall. Nitrite, nitrate, and silicates tend to be high in the Pooles Island area due to tributary inputs (Boynton et al. 1996). Ammonia, the preferred nitrogen source for phytoplankton, tends to be low and variable in the region (Magnien et al. 1990).

Chlorophyll a concentrations are generally low due to the increased turbidity in the region (Michael et al. 1991). Particulate phosphorus carried in the freshwater flows binds to sediment particles as it encounters saline water (MES 1997a). Total phosphorus in the region tends to be elevated due to the resuspension of bottom sediments (Michael et al. 1991). Several studies have been conducted to monitor the water quality effects of placing dredged material (Michael et al. 1991) and to evaluate the water quality impacts caused by nutrients released from dredged sediments placed at Pooles Island (Dalal 1996b). Second-year placement monitoring at G-West indicated that water quality in the region compared well to the background locations. No significant long-term (month to season) changes in water quality were detected for the Pooles Island area. Trends for nutrients in the region are provided in EA 1997.

Gyre Circulation

Numerical modeling conducted in 1992 revealed the possible existence of a gyre circulation pattern in the Upper Chesapeake Bay (Wang 1992). The hypothesized clockwise flow begins southeast of Pooles Island, flows north to south along the eastern shoreline of the Bay until Swan Point, then turns southwest and west toward HMI. The numerical modeling indicated that this circulation pattern may be important to effluent dispersion from HMI and flow into Back River and thus to general water quality in the region. This gyre circulation and the potential effects of island placement on gyre circulation are addressed more specifically in the hydrodynamics section (Moffatt and Nichol 1997). Gyre effects are acknowledged in this section due to the potential water quality effects associated with changes in the gyre circulation pattern. Concerns raised by resource agents (Nick Carter, MDNR, August 1997) regarding exacerbation of water quality problems due to recirculation of HMI effluents were also considered. Benthic monitoring in the vicinity of HMI has reflected no observable differences in benthic populations relative to reference locations as a result of HMI outputs (MDNR 1995).

7.2.2 Benthic Community and Habitat

Benthic communities provide a major trophic link in the Chesapeake Bay food chain. Benthic community structure is dictated by a variety of factors including sediment composition, salinity, and sediment quality. Benthic community structure in relation to habitat and environmental and anthropogenic stress has been studied extensively within the Chesapeake Bay ecosystem (Versar 1988; Ranasinghe et al. 1993, 1994a, 1994b, 1994c, 1996). The physical, chemical, and biological composition of the benthic environment within the proposed placement sites provides important information that will be used to characterize the relative condition (or health) of the site, the habitat quality available to higher trophic levels at the site (such as fish), and the suitability of the site for construction.

7.2.2.1 Sediment Composition

Sediment composition varies throughout the Bay and is one of the major physical factors that influences benthic community structure. Many fish species prefer specific sediment and bottom types for foraging and spawning opportunities. In addition to influencing the biological communities, sediment composition dictates the type and size of the placement facility that can feasibly be constructed. Although the latter is a consideration more from a facility costing perspective, the type of facility (i.e., size, height, sub-aqueous, or emergent) that can feasibly be built on a site, can influence the ecological assessment of the site.

Sediment composition is described in the following sections based upon several recent and historical surveys. EA collected site-specific surficial samples at each of the benthic sampling stations in August 1997; Maryland Geologic Survey (MGS) provided site-specific subprofiling acoustic data of several of the proposed dredged material placement sites (1997; see Appendix); E2Si (1997) conducted borings in each of the proposed placement sites. Other sediment composition information has been included, as available.

Site 1

According to data collected by MGS (1997 and 1988) and E2Si (1997), the predominant sediment type at Site 1 is sand. Sand was also the major component in three of the five samples collected by EA at this site (EA 1997). Although sand was the predominant sediment type, clayey silt was reported in the extreme east-northeast portions of the site (MGS 1997; EA 1997). Organic content for the site ranged from 0.9 percent to 14.5 percent (EA 1997).

Overall, of the five proposed sites, Site 1 contained the largest and most uniform location of hard sand bottom. This site was evaluated the highest for both foundation and borrow criteria (E2Si 1997), and is therefore, from a construction viewpoint, the best site for placement of a containment facility.

Site 2

Silty clay and clayey silt are the predominant sediment types at Site 2, based upon MGS (1988), E2Si (1997) and EA collections (EA 1997). The bottom sediments are homogeneous throughout the region. Organic content for the site ranged from 8.5 percent to 10.4 percent (EA 1997). Overall, the site has a fairly soft bottom and was less desirable for both foundation and borrow criteria (E2Si 1997).

Site 3

Silty clay and clayey silt are the predominant sediment types at Site 3, based upon the MGS (1997 and 1988), E2Si (1997) and EA collections (1997). The bottom sediments are homogeneous throughout the region. Organic content ranged from 9.6 percent to 11.9 percent (EA 1997). Overall, the site has a fairly soft bottom and was evaluated as the least desirable for both foundation and borrow criteria (E2Si 1997).

Site 4A

All surficial collections by E2SI, MGS, and EA represent conditions outside of the Aberdeen Proving Ground boundary.

Clayey silt was the predominant sediment type at Site 4A, based upon data collected by MGS (1988), E2SI (1997), and EA (1997). The sediment composition was homogeneous throughout the site. Organic content ranged from 7.9 percent to 11.5 percent (EA 1997).

The predominance of clayey silt sediments in the site is the result of unconfined dredged material placement at this site within recent years. Between November 1991 and March 1992, 0.5 million cubic yards (mcy) of uncontaminated sediments dredged from the Chesapeake and Delaware (C&D)

Approach Channel and 1.8 mcy from the Tolchester Channel were placed at sites near Pooles Island (Ranasinghe and Richkus 1993). Sediment characterization of the G-East site by MGS in 1996 also characterized the sediments in the region as clayey silt - silty clay (Halka et al. 1996), and benthic community assessments of the G-West site categorized the sediments as clayey silt (Dalal 1996).

Site 4B/4B-R

The sediment composition is heterogeneous throughout Site 4B based upon MGS data (1997), E2SI (1997), and EA data (1997). The substrate to the east-southeast of Pooles Island is predominantly sand, and substrate to the south varies from sand to clayey silt (MGS 1997 and EA 1997). E2SI found sand immediately south of the island and clayey silt further south (in the vicinity of Site 4B-R).

Organics content in the region ranged from 1.6 percent to 9.9 percent (EA 1997). The substrate immediately surrounding the eastern, southern, and western shore on Pooles Island consists of cobble (MGS 1997 and personal observations by EA). Kaltenbacher (1996) described the area as follows: "the entire island is geomorphically underlain by a bed of well graded cobbles and stones which acts as a natural 'rip-rap.'" Of the five proposed island placement sites, Site 4B contains the most heterogeneous bottom substrate, and the cobble habitat is unique to this site. According to MGS data (1997), cobble habitat does not extend south to the vicinity of 4B-R.

7.2.2.2 Sediment Quality

Sediment quality influences aquatic biota. Elevated sediment contaminant concentrations may stress the ecosystem and cause adverse effects to the biological communities. Trace metals are one category of sediment contaminants. According to Bay-wide sediment contaminant studies (1984-1991), the highest and most variable trace metal concentrations are found in the upper Bay region from Pooles Island to the Bay Bridge (Eskin et al. 1994).

Sediment quality was evaluated for each of the proposed island placement sites based upon data for trace metal concentrations. Trace metal concentrations were determined for sediments collected from two stations within each of the five proposed sites. These data were compared to No Observed Effect Level (NOEL) and Probable Effect Level (PEL) values. No adverse toxic effects are expected if contaminant values fall below the NOEL. Values that fall between the NOEL and the PEL may cause *possible* adverse toxic effects to biological organisms. Sediment contaminant levels that exceed the PEL have a *significant probability* of causing adverse toxic effects to aquatic biota.

Analytical sediment data for samples collected from the upper Bay in 1997 are presented in EA 1997. To assess sediment quality, the eight trace metals that are monitored in the Bay were compared with PEL guidelines described in MacDonald (1993) (Table 7-2). Trace metal concentrations were normalized by dividing the bulk metal concentration in the sediment by the fraction of sediment that consisted of particles less than 62μm (Horowitz 1985) (Table 7-2). These methods are consistent with those employed in Bay-wide sediment contamination studies conducted in 1984-1991 (Eskin et al. 1994).

Sites were categorized based on trace metals either falling below the NOEL, falling between the NOEL and PEL, or exceeding the PEL. The limitations of these analyses are as follows (Eskin et al. 1994):

- PEL concentrations were developed to characterize the *potential* for sediments to produce toxic or adverse effects;
- PEL values are derived from a multitude of studies with varying locations, biota, and contaminants sources;
- At any given site, toxicity effects may vary depending on the physical and chemical characteristics of the sediment, the presence of other contaminants, synergistic effects of multiple contaminants, and the sensitivity and composition of the resident biota.
- NOEL and PEL guidelines do not account for factors such as the presence of acid volatile sulfides that influence bioavailability.

The following descriptions of sediment quality at the proposed island placement sites are derived using the data collected by EA in 1997, unless otherwise specified.

Site 1

The average normalized concentration of zinc (828.43 mg/kg) exceeded the PEL value (Table 7-2). Zinc is a Candidate for listing as a Chesapeake Bay Toxic of Concern, but additional information is required to determine its status. Zinc is used in manufacturing processes but is naturally found in soils and rocks. Anthropogenic inputs include industrial and municipal wastewater effluents and urban storm water. Eskin et al. (1994) determined the median sediment concentration of zinc in the mainstem of the Chesapeake Bay to be 136 ppm, and maximum concentrations of zinc were reported in the vicinity of MCB3.2, south of proposed Site 1 (see Figure 7-1). Elevated, naturally-occurring concentrations of zinc exceeding the level found by Eskin et al. (1994) have been documented in upper Bay sediments by studies conducted for CENAB (EA 1996). Concentrations of all other trace metals, with the exception of nickel which has no NOEL/PEL guidelines, were below the PEL but above the NOEL. Based on these results, the site was categorized as having probable adverse effects associated with zinc concentrations.

<u>Site 2</u>

The average normalized concentration of cadmium (7.6 mg/kg) exceeded the PEL value (Table 7-2). Sources of cadmium are industrial and municipal effluents, landfill runoff, and other nonpoint sources. Cadmium is also naturally found in soils and rocks. Eskin et al. (1994) found the median sediment concentration of cadmium in the mainstem of the Chesapeake Bay to be 0.4 ppm and maximum concentrations were reported in the upper Bay in the vicinity of MCB3.1 and MCB3.2 (see Figure 7-1). Concentrations of arsenic, copper, lead, and mercury were below the PEL but above the NOEL guidelines. Chromium was the only metal, excluding nickel, below NOEL guidelines. Based on these results, the site was categorized as having probable adverse effects associated with cadmium concentrations.

<u>Site 3</u>

Average normalized concentrations of all metals, excluding nickel, were between PEL and NOEL guidelines (Table 7-2). Based on these results, the site was categorized as having only possible adverse effects associated with any of the select trace metals, except nickel. The possibility of toxic effects would have to be confirmed through further study during the feasibility phase.

<u>Site 4A</u>

Average normalized concentrations of arsenic (9.37 mg/kg), cadmium (5.86 mg/kg), lead (26.72 mg/kg), mercury (0.27 mg/kg), and zinc (155.11 mg/kg) were below PEL guidelines but above NOEL guidelines. Chromium and copper concentrations were below the NOEL guidelines (Table 7-2). Based on these results, the site was categorized as having possible adverse effects associated with arsenic, cadmium, lead, mercury, or zinc. The possibility of toxic effects would have to be confirmed through further study during the feasibility phase.

In Fall 1995, CENAB performed sediment sampling and chemical analysis at a reference station east of Pooles Island (EA 1996). Metal concentrations were characterized as similar or less than those typical of outer channel material. Chromium, copper, and lead values for sediments at Pooles Island were below the NOEL, and arsenic, cadmium, mercury, and zinc were below probable effects level (PEL) values. Two semivolatile polycyclic aromatic hydrocarbons (PAHs) were detected in Pooles Island sediments: benzo(b) fluoranthene and phenanthrene; no NOEL or PEL values have been developed for benzo(b)fluoranthene, and phenanthrene was below the NOEL. Toxicity testing of material prior to placement indicated no toxicity to amphipods (Versar 1994).

<u>Site 4B/4B-R</u>

The average normalized concentration of zinc (793.8 mg/kg) exceeded the PEL value (Table 7-2). Concentrations of all other metals, except nickel and cadmium, were between PEL and NOEL guidelines. Cadmium values fell below the NOEL guideline. Based on these results, the site was categorized as having probable adverse effects associated with zinc concentrations. Although no site-specific sediment quality information is available for Site 4B-R, sediment quality of Site 4B-R is considered to be similar to the condition at Site 4-B within this section.

7.2.2.3 Benthic Community Composition

Benthic macroinvertebrate communities are important components of the Chesapeake Bay ecosystem. Benthic organisms provide a major trophic link from phytoplankton to higher trophic levels (Virnstein 1977; Holland et al. 1980; Baird and Ulanowicz 1989). They also serve as important food source for fish and crabs (Homer et al. 1980; Virnstein 1979; Homer and Boynton 1978); and play a role in the cycling of nutrients from sediments into the water column (Kemp and Boynton 1981; Boynton et al. 1982).

Benthic communities are good biological indicators of environmental or anthropogenic stress in aquatic communities. They have limited mobility and are unable to avoid adverse conditions (Gray 1979). Benthos live in sediments where contaminants may accumulate, they have relatively short life spans, and they include a variety of organisms with a wide-range of feeding modes, trophic guilds, and physiological tolerances (Pearson and Rosenberg 1978; Rhoads et al. 1978). Environmental and anthropogenic stresses are reflected in local community structure. Natural habitat characteristics such as salinity, substrate, and depth also influence benthic community composition (Holland et al. 1987).

The SOM has monitored benthic communities throughout the Maryland portion of the Chesapeake Bay since 1984. This long-term benthic monitoring program provides a comprehensive dataset that includes communities in a variety of habitats (Ranasinghe et al. 1994a), and has been used in conjunction with other existing datasets to develop Chesapeake Bay Benthic Community Restoration Goals (Ranasinghe et al. 1994b) and a Benthic Index of Biotic Integrity (B-IBI) (Weisberg et al. 1997).

Indices of biotic integrity are widely used in other aquatic systems to evaluate site conditions based on expected conditions at reference locations (Karr 1991; Kerans and Karr 1994). The B-IBI has been peer-reviewed and validated, and uses a multi-metric approach to characterize the condition or "health" of the benthic community. The B-IBI provides researchers with a tool to evaluate relative community health. Attributes of estuarine benthic communities such as diversity, abundance, biomass, proportions of pollution-sensitive and pollution-indicative taxa, and trophic feeding guilds are evaluated based upon a range of expected values derived from reference locations in habitats with similar substrate and salinity characteristics. Metrics (attributes) are salinity and substrate specific to minimize variability associated with habitat type. Metrics are evaluated as 5, 3, or 1, depending on whether they approximate, deviate slightly, or deviate strongly from conditions at reference locations (Weisberg et al. 1997). Benthic communities with an average score less than three are considered stressed.

For additional information regarding metric attributes, scoring criteria, and feeding guild classifications, refer to Ranasinghe et al. 1996 and Weisberg et al. 1997.

In order to evaluate the benthic communities in each of the five proposed placement sites, screening-level conditions were summarized and compared to appropriate regional long-term benthic data (areas of similar salinity and substrate type). In addition, B-IBI metrics were computed using the screening-level information to determine the relative condition of the sites.The B-IBI scores were used and interpreted for screening-level analyses only, and are not intended to definitively categorize condition at the sites. Additional sampling and replication are required to provide a measure of variability within each site. Importantly, although the B-IBI is capable of identifying areas with stressed benthic communities, it does not distinguish between natural and anthropogenic stressors (Weisberg et al. 1997).

<u>Site 1</u>

The benthic community habitat at Site 1 is categorized as a low mesohaline area containing sand, clayey silt, and sandy oyster shell bottom. The habitat and the benthic community structure is heterogeneous within the region (EA 1997). Total number of taxa ranged from 7-17 taxa at the five sampling locations, and a total of 22 distinct taxa were collected throughout the site.

Grab samples were numerically dominated by mollusks and annelid worms. The polychaete *Marenzellaria viridis* was the predominant annelid contributing 5.7 percent to 70.6 percent to total abundance. The gastropod *Littoridinops tenuipes* and the bivalve *Rangia cuneata* were the prevalent mollusks in the clayey/silt habitats, comprising 30.7 percent to 57.7 percent of total abundance. *Macoma mitchelli* was the numerically dominant mollusk in the sandy habitats, contributing 11.8 percent to 22.3 percent. The amphipod *Leptocheirus plumulosus* and the isopod *Cyathura polita* were the numerically dominant arthropods at all five sampling locations. Mollusks dominated total biomass at all stations, contributing 84–99 percent to total biomass values (EA 1997). All of these species are typical for this portion of the Bay in comparable habitats (Ranasinghe et al. 1994a). Species lists by station for Site 1 and an overall summary of the community at Site 1 are provided in EA 1997.

Screening level values for B-IBI metrics are provided in Table 7-3. The average B-IBI score for Site 1 was 3.4 (Table 7-4), based upon scoring criteria developed for low mesohaline habitats (Ranasinghe et al. 1996; Weisberg et al. 1997). Communities with an average score less than three are considered stressed. There are currently no other existing datasets that describe the benthic community in this discrete area of the Bay.

Site 2

The benthic community habitat at Site 2 is categorized as high mesohaline clayey silt. The bottom substrate/habitat is homogenous throughout the region, and benthic communities at each station are similar (EA 1997). The total number of taxa ranged from 12 to 17, and all stations combined yielded 18 taxa.

Annelids numerically dominated the grab samples at Site 2 and were comprised of similar proportions of polychaetes and oligochaetes. *Streblospio benedicti* and *Heteromastus filiformis* were the dominant polychaete species, contributing 2.1 to 13.1 percent and 5.1 to 7.9 percent to total abundance, respectively. Oligochaetes contributed 18.5 percent to 24.7 percent to total abundance. *Leptocheirus plumulosus* was the dominant amphipod contributing approximately 17.8 percent to 38.6 percent to total abundance estimates. Although not numerically dominant, mollusks dominated biomass at all sampling stations, gravimetrically contributing 79–96 percent to total biomass estimates (EA 1997). These species are typical for high mesohaline regions of the Bay that experience seasonal hypoxia (Ranasinghe et al. 1994a). Species lists by station and a summary of the community at Site 2 are provided in EA 1997.

Screening-level values for B-IBI metrics are provided in Table 7-3. The average B-IBI score for Site No. 2 was 2.3 (Table 7-4), based upon scoring criteria developed for high mesohaline mud habitats (Ranasinghe et al. 1996; Weisberg et al. 1997). Communities with an average score less than three are considered stressed. Impaired benthic community structure at this site may be due to naturally occurring hypoxia events during the summer months.

Site 3

The benthic community habitat at Site 3 is categorized as high mesohaline clayey silt. The bottom substrate and community composition at Site 3 is homogenous throughout the site (EA 1997). The number of taxa collected at Site 3 ranged from 9-13 taxa, and all stations combined yielded a total of 17 distinct taxa.

Annelids numerically dominated the samples at Site 3 and were comprised of similar proportions of polychaetes and oligochaetes. *Streblospio benedicti* was the dominant polychaete species, numerically contributing 3.8 percent to 33.9 percent to total abundance estimates. Mollusks, primarily the bivalve, *Macoma balthica*, contributed 17.3 percent to 39.7 percent to total abundance. *Leptocheirus plumulosus* was the dominant arthropod at sampling locations, contributing 2.2 percent to 28.1 percent to total abundance. Mollusks dominated biomass at all sampling stations, contributing 96–99 percent to biomass (EA 1997). These organisms are typical for communities in mesohaline regions that experience seasonal hypoxia (Ranasinghe et al. 1994a). Species lists by station and a summary of the community composition at Site 3 are provided in EA 1997.

Screening-level values for B-IBI metrics are provided in Table 7-3. The average B-IBI score for Site No. 3 was 1.7 (Table 7-4), based upon scoring criteria developed for high mesohaline mud habitats (Ranasinghe et al. 1996; Weisberg et al. 1997). Communities with an average score of less than three are considered stressed. Site 3 lies within the Chesapeake Bay Long-Term Benthic monitoring station/stratum 107 (high mesohaline mud) (Ranasinghe et al. 1994a and 1996). Metric scores for this station during the period of 1990–1993 categorized the benthic community condition as stressed or impaired (Ranasinghe et al. 1996). The benthic community at this site may be impaired due to naturally occurring hypoxia events during the summer months.

Site 4A

The benthic community at Site 4A is categorized as low mesohaline clayey silt. The region at Site 4A has historically been used for unconfined placement of sediments dredged from the approach channels to the C&D canal. The habitats sampled at Site 4A included only those located outside the perimeter of APG. The clayey silt substrate was homogeneous throughout the sampling area. The number of taxa collected ranged from 9-15 taxa, with a combined total of 21 distinct taxa collected within the region (EA 1997).

Annelids, primarily the polychaete *Marenzellaria viridis,* were numerically dominant at all stations except station 4, contributing 14.8 percent to 50.9 percent to total abundance. The bivalve *Rangia cuneata* numerically dominated abundance at station 4, contributing 67.2 percent. An isopod, *Cyathura polita*, was the dominant arthropod collected at all stations, contributing 7.1 percent to 18.0 percent to total abundance. Mollusks were gravimetrically dominant at all sampling stations, contributing 58–97 percent to total biomass. Species lists by station and a summary of the community composition at Site No. 4A is provided in EA 1997.

Screening-level values for B-IBI metrics are provide in Table 7-3. The average B-IBI score for Site 4A was 3.4 (Table 7-4), based upon scoring criteria developed for low mesohaline habitats (Ranasinghe et al. 1996; Weisberg et al. 1997). Communities with an average score of less than three are considered stressed. Site 4A lies within the Chesapeake Bay Long-Term Benthic monitoring area (stratum) 108 (low mesohaline mud) (Ranasinghe et al. 1994a and 1996). Metric scores for this area during the period of 1990–1993 categorized the benthic community condition as meeting the Chesapeake Bay Restoration Goal (Ranasinghe et al. 1996).

Sampling by ICF Kaiser in August 1995 revealed that a site located approximately 1 mi northeast of Site 4A between Fairlee and Worton Creeks (Neubauer and Thomas 1996) was numerically dominated by *Rangia cuneata* (97 percent). The Shannon-Wiener Diversity Index for this region was substantially lower (0.291) than diversity reported for the 4A region in August 1997.

Because unconfined placement of dredged material has occurred within Site4A since the early 1990s, MDE (Dalal 1996a) and other consultants (Ranasinghe and Richkus 1993) have monitored the structure of the benthic communities in the region. During a placement activity in 1994, a berm was created using 530,000 cy of clayey-silt that originated from maintenance dredging of the C&D canal approach channels. There have been three subsequent placement events (1994–1997) that have deposited a total of approximately 3.2 mcy of maintenance material (Cece Donovan, MES, November 1997). Benthic monitoring at G-West was conducted by MDE in September 1995 (Dalal 1996a) to determine if the benthic community had re-established 18 months after berm construction and to determine if the community met the Chesapeake Bay Program's Restoration Goal (Ranasinghe et al. 1994b). Results indicated that 4 of 5 stations sampled on the berm did not meet restoration goals, and overall, the benthic communities had not fully re-established. Continued placement has, however, contributed to the length of time needed to recolonize. Although the benthic communities were not fully re-established, results indicated that community diversity had increased since August 1994.

<u>*Site 4B/4B-R*</u>

The benthic community habitat at Site 4B is categorized as low mesohaline containing sand, clayey silt, silty sand, and sandy clay silt. The habitat and benthic community composition was heterogeneous and varied at each sampling station (EA 1997). The number of taxa ranged from 10-16 taxa, and a combined total of 21 distinct taxa were collected throughout the site.

The dominant taxonomic groups varied at each station. The polychaete *Marenzellaria viridis* was present at all five stations, contributing 6.7 percent to 29.6 percent to total abundance. Oligochaetes contributed 11.9 percent to 26.8 percent to abundance at Stations 1,3, and 5. *Rangia cuneata* was an important species at all stations, except station 3, numerically contributing comprising 15.3 percent to 76.3 percent of total abundance. Dominant arthropods included the amphipod *Leptocheirus plumulosus* and the isopods *Cyathura polita* and *Chiridotea almyra*. Mollusks dominated biomass at all sampling stations, except Station 3, gravimetrically comprising 89–98 percent of total biomass. Arthropods were gravimetrically dominant at Station 3 (EA 1997). All species are typical for low mesohaline regions of the Bay (Ranasinghe et al. 1994a). Species lists by station and a summary of the community composition at Site 4B is provided in EA 1997.

Screening-level values for B-IBI metrics are provided in Table 7-3. The average B-IBI score for Site 4B was 3.0 (Table 7-4), based upon scoring criteria developed for low mesohaline habitats (Ranasinghe et al. 1996; Weisberg et al. 1997). Communities with an average score of less than three are considered stressed. Site No. 4B lies within the Chesapeake Bay Long-Term Benthic monitoring stratum 108 (low mesohaline mud) (Ranasinghe et al. 1994a and 1996). Metric scores for this site during the period of 1990–1993 categorized the benthic community condition as meeting the Chesapeake Bay Restoration Goal (Ranasinghe et al. 1996).

A portion of Site 4B is located within APG, and the proposed island alignment abuts Pooles Island. According to APG personnel (Steve Wampler, APG, August 1997) and based upon observations during a recent site visit, cobble habitat is prevalent along the southern, eastern, and western shorelines of the island and extends to varying degrees into the shallow water habitat surrounding the island. Due to restrictions placed by APG, benthic communities in the cobble habitat were not sampled. This substrate, however, is unusual and limited within the Chesapeake Bay, and likely supports a unique benthic community that differs from habitats evaluated in the other study sites. The potential value of this habitat has not been quantified, but will be considered during numerical evaluations. The presence of shallow water cobble bottom in the vicinity of Pooles Island, if confirmed, will essentially preclude the use of Site 4B for placement of dredged material under the Section 404 B guidelines.

Although not qualitatively or quantitatively sampled, the benthic community at Site 4B-R is expected to be similar to Site 4B based upon comparable depth and substrate characteristics.

7.2.3 Fisheries and Fish Habitat

Finfish and shellfish in the Chesapeake Bay are valuable commercial and recreational fisheries resources. The upper Bay also supports a diverse fish community beyond those recognized as recreational or commercial finfish species. A list of finfish species that are likely to occur in some portion of the study area (i.e., mesohaline areas of the Bay) is provided in EA 1997. Of these species, white perch, herrings, and striped bass are the most economically valuable of the recreationally or commercially important finfish species and are the target finfish species for this study. Oysters, soft clams, and blue crabs are the most commercially important shellfish and are also collected recreationally, although oysters are predominantly harvested in the lower reaches of the upper Bay at the present time (Chris Judy, MDNR, August 1997). These shellfish were the target species for this study. Many other species are, however, fished commercially and recreationally.

For the purposes of this assessment, the description of the fishery is restricted to recreational and commercial aspects, because this portion of the fishery has a tangible value to resource agents and the public. However, the fish community as an ecological resource will have to be evaluated as part of the feasibility phase of this project. To the extent possible, habitat value and potential effects of island construction have been included in discussions of the commercial fishery.

7.2.3.1 Recreational Fisheries

For the purpose of the prefeasibility study, recreational fisheries will be limited to finfish. Although shellfish are part of the overall Bay recreational fishery, finfish likely make up the major recreational fishery in the sites being considered as part of this project. This is particularly true since blue crabs have a shorter seasonal distribution in the upper Bay than in other areas closer to the blue crab spawning areas near the mouth of the Bay. Additionally, the value of a site as nursery and spawning habitat for important species will be discussed under the commercial fishery section. In the Upper Chesapeake Bay, recreational fisheries exist for many species including the target species for this investigation. Recreational fishing includes private boats as well as charter boats. Although the five sites may vary with importance to the local recreational fishery, it is unlikely that the elimination of any one of these sites (by itself) will significantly affect the catch-per-unit-effort (CPUE) of the upper Bay recreational fishery due to the relative site sizes in relation to similar available habitats in the upper Bay. This statement is consistent with the conclusions contained in the G-East and Site 92 Environmental Assessment (MES 1997a). Alteration of bay bottom to upland habitat may, however, contribute to an incremental decrease in CPUE, particularly when considered with other factors that adversely affect the fishery.

Site 1

There are no existing data quantifying the recreational fishery specifically at this site. However, there is a permitted "fish haven" (Gales Lump Reef) immediately to the northeast of this site. The fish haven is an area where structure in the form of old concrete and steel objects can be deposited to form an artificial reef. The permit for this area had been transferred from MDNR to MES (Foster 1997). In addition, the relatively sandy substrate and the non-uniformity of depth both in and adjacent to the site provides suitable habitat to support a recreational fishery. Although the fish haven is not very productive, striped bass are commonly targeted by recreational anglers in several areas of Site1 (Lawrence Thomas, MCBA, August 1997). Sites similar to Site1 have the potential to support a moderate to good recreational fishery based upon the data collected for the Blackstone Site (immediately north of Site1) (MES 1997a).

Site 2

There are no existing data quantifying the recreational fishery specifically at this site. This site has predominately a silt/clay substrate and is relatively uniform in depth with the exception of the northeast corner of the proposed site which exhibits a gradual increase in depth to approximately -26 ft (MLLW). Because of these uniform characteristics and the absence of any nearby structure, Site2 probably does not support a locally important recreational fishery (Lawrence Thomas, MCBA, August 1997). The site is also expected to become hypoxic in summer and hypoxic conditions were measured at Site 2 during the EA field surveys (EA 1997).

Site 3

There are no existing data quantifying the recreational fishery specifically at this site. This is the deepest of the five sites with water depths of -38 ft (MLLW) in the northeast corner and demonstrated hypoxic conditions during EA surveys. This site also has a very soft bottom comprised mostly of silt/clay. Much of the area surrounding Site 3 is high relief bottom that is actively fished by recreational anglers (Lawrence Thomas, MCBA, August 1997). Because some ledge-type habitat exists on the fringes of the site, some anglers may use it, but the adjacent areas (outside of the site) are more likely to be fished for striped bass (Lawrence Thomas, MCBA, August 1997).

Site 4A

There are some existing data on the quality of the recreational fishery in the vicinity of Site 4A. These data were collected by MES as part of the environmental assessment of G-East and Site 92. The G-East site in this study is in close proximity to Site 4A of the current study. This area of the upper Bay is used by charter boats to fish for striped bass, but other species such as white perch are also targeted in the Pooles Island area. Studies conducted by MES indicated that the area was considered locally important to recreational fishing activity. In a charter boat angling study, Site 4A yielded approximately one-half of the CPUE of the two control sites located south of Pooles Island, but was considerably higher than Site 92 also located south of Pooles Island (MES 1997a). Further examination of NMFS recreational fisheries statistics and a MDNR database tended to support the overall findings that the Pooles Island area may be locally important, but in context of the upper Bay was not a significant contributor to the overall recreational catch (Miller and McCracken 1997). The habitat features of Site 4A, particularly the non-uniform depth distribution resulting from localized shoals, would indicate that this site has the potential to be an important local area for the recreational fishery and is, in fact, heavily fished at certain times of the year by charter boats (Lawrence Thomas, MCBA, August 1997).

Site 4B/4B-R

Unlike Site 4A, there are much fewer existing data on the recreational fishery in Site 4B. Although these two sites are located geographically close together, the habitat features differ markedly. Site 4B is generally uniform in depth with the exception of the area in the immediate vicinity of Pooles Island. Because of the location immediately downstream and to the west of Pooles Island, Site 4B is in an area that is somewhat protected from the greatest tidal currents. Part of the site also contains high relief bottom which was being fished intensively by recreational anglers during EA surveys of Pooles Island. Site 4B-R is in an area of deeper water and uniform bottom, and has less potentially important recreational fish habitat.

7.2.3.2 Commercial Fishery

For the purposes of this section, commercial fishery includes both finfish and shellfish. In addition to specific harvest areas for the commercially important species, the potential value of an area as spawning habitat and/or nursery habitat and potential effects of island hydrodynamics are also discussed. The following discussion is primarily based upon four data sources: (1) the NOAA 1996 data compilation map (see EA 1997); (2) MES 1997b; (3) Funderbunk et al. 1991; (4) Lippson 1973. These resources generally have consistent interpretations of important nursery areas, spawning areas, and areas of general abundance for the species being considered as commercially important. Additionally, historical harvesting information was obtained from the Maryland Waterman's Association report (MWA 1978) and updated through personal communications with resource agents, Larry Simms of the Maryland Watermen's Association (MWA) and Daniel Beck of the

Baltimore Watermen's Association (BWA). The commercially important shellfish species include American oyster, softshell clam, and blue crabs. The commercially important Finfish include striped bass, white perch, herring and (to a lesser extent) the spot, croaker, and weakfish family (drums). A map of the Charted Oyster Bars and other shellfish areas in proximity to the proposed sites is presented in Figure 7-2. In addition, several areas that are not designated are also harvested by commercial fishermen (Larry Simms, MWA, October 1997). Oyster bars in the upper Bay are less susceptible to disease (such as MSX and Dermo) due to the lower salinities above the Bay Bridge (Larry Simms, MWA, October 1997.

As part of this prefeasibility study the general distribution of commercially important species as well as high value habitat areas were the main focus of evaluation. The intensity of use of these sites for commercial fisheries varies considerably by fishery and season. A thorough investigation of the fisheries resources and commercial harvests should be considered for the feasibility phase of this study.

There have been some recent fisheries studies conducted in the vicinity of Pooles Island (primarily in Site 4A) and close to Site 1 as part of the environmental assessment for G-East and Site 92 conducted by MES. In general, these studies indicate that there is no evidence of unique characteristics in these areas and the fishery around Pooles Island was similar to reference sites in terms of species composition and age structure (Miller and Sadler 1997, Weimer et al. 1996, Lou and Brandt 1993). This finding does not suggest that these areas are unimportant to the Bay fishery, but rather indicates that they may not be as important as some other areas in the Bay for commercial harvest. Further studies would be required at each of the sites to better quantify the existing fishery resource and the commercial and recreational fishery stemming from that resource during a feasibility phase of study.

Site 1

Site 1 is in suitable habitat for some important commercial fish species. In terms of shellfish, Site 1 has suitable habitat and lies within the general distribution of soft shell clams, oysters, and blue crabs. Oysters do occur and thrive as far north as Tolchester Beach (Daniel Beck, BWA, September 1997) although a couple of consecutive years of higher salinities in the area are required for areas that far north to be very productive (Chris Judy, MDNR, August 1997). No charted oyster bars occur within the boundaries of Site 1 (Figure 7-2), but some charted oyster bars are located in general proximity to the site. Site 1 is in the low density area of the Bay for soft shell clams, but because of the presence of a sandy substrate, soft shell clams are likely to occur within the site (Chris Judy, MDNR, August 1997) and clams are occasionally harvested from the site (Daniel Beck, BWA, September 1997). Site 1 is intensively crabbed throughout the summer (Daniel Beck, BWA, September 1997). In terms of Finfish at Site 1 historical information indicates that it is an important area for Finfish harvests (MA 1978) and the area is still intensively fished for striped bass and white perch (drift netted) during winter (Daniel Beck, BWA, September 1997). Site 1 is in the general nursery area for white perch, American shad, and other herring species (Funderburk et al. 1991) and some of the site may be a major summer concentration area for striped bass (Lippson 1973). Site 1 lies in an area of the upper Bay that is relatively wide and at least four miles south of the regulated striped bass spawning area. Alterations in hydrodynamics as a result of island construction at Site 1 may alter upper Bay currents or the extent of the salt wedge to the point that larval fish distributions would be affected. This would, however, need to be confirmed with more intensive hydrodynamic investigations during future phases of study.

Site 2

Due to the depths and silty substrate at Site 2, it would not be suitable habitat for soft shell clams or oysters. Site 2 includes areas of sufficient depth that hypoxic conditions can occur in warmer months. Therefore, in some years it is probably not an important area for commercial crab or finfish harvests in the summer. In years where hypoxia is less wide spread, Site 2 is intensively crabbed, particularly during those times when crabs are best caught as they are moving into or out of deeper waters (spring/fall) (Daniel Beck, BWA, September 1997). Site 2 is among those that are heavily fished for striped bass and white perch (drift netted) during winter and is relatively productive (Daniel Beck, BWA, September 1997).

Site 2 does not appear to be an important spawning or nursery area for the target species considered in this review, with the possible exception of being a nursery area (for larger juveniles) of spot (Funderburk et al. 1991). Site 2 lies in an area of the upper Bay that is relatively wide. Alterations in hydrodynamics as a result of island construction at Site 2 are not expected to alter upper Bay currents or the extent of the salt wedge to the point that larval fish distributions would be affected. This would, however, need to be confirmed during more intensive hydrodynamic investigations during future phases of study.

Site 3

Site 3 includes many of the same characteristics and fisheries issues as Site 2. Specifically, the depths and silty substrate are not suitable habitat for soft shell clams or oysters and the site includes areas of sufficient depth that hypoxic conditions can occur in warmer months. Therefore, in some years it is probably not an important area for commercial crab and finfish harvests in the summer. In years where hypoxia is less wide spread, parts of Site 3 are intensively crabbed, particularly during those times when crabs are best caught as they are moving into or out of deeper waters (spring/fall) (Daniel Beck, BWA, September 1997). Site 3 is among those that are heavily fished for striped bass and white perch (drift netted) during winter and is relatively productive (Daniel Beck, BWA, September 1997). Additionally, there are no charted oyster beds within the boundaries of Site 3, but there is a very large oyster bar directly west (NOB 4-2, Fig. 7-2). The current configuration of the submerged island site (Site 3S) includes an area within the boundaries of NOB 4-2, although at this phase of planning it is probably a mapping phenomenon as the site was intended to be in deeper waters.

Site 3 is not an important spawning or nursery area for the target species considered in this review Site 3 lies in an area of the upper Bay that is relatively wide. Alterations in hydrodynamics as a result of island construction at Site 3 may alter upper Bay currents or the extent of the salt wedge to the point that larval fish distributions would be affected. This would, however, need to be confirmed during more intensive hydrodynamic investigations during future phases of study.

Site 4A

Site 4A is generally located in an area that has the potential to support various lifestages of commercially important species. In terms of shellfish, this site is located too far to the north to support soft shell clams and oysters except in extreme prolonged drought conditions (Chris Judy, MDNR, August 1997). Site 4A is crabbed intensively throughout the summer (Daniel Beck, BWA, September 1997) and a significant crab harvesting effort was noted adjacent to Site 4A during the EA trip to Pooles Island. Site 4A is among those that are heavily fished for striped bass and white perch (drift netted) during winter and is relatively productive (Daniel Beck, BWA, September 1997). Portions of the site that lie within the APG controlled area (boundary) would be off limits to commercial harvesting when the area is closed.

Most of the finfish species listed above as commercially important use the general vicinity of Site No. 4A during some portion of their lifestage. White perch use the area around Pooles Island for spawning. The adults of striped bass, white perch, herring, and the spot, croaker, weakfish family also are generally distributed in this area (Funderburk et al. 1991). However, of more importance is that this site is considered as a nursery area for all of these species and as such has the potential to be important to the overall commercial fishery of the upper Bay. Gillnet studies of the site indicated higher catch rates for small striped bass in high relief areas of the site relative to lower relief areas, indicating a seasonal importance of the site to this species (MES 1997a). Although the site lies wholly outside of the regulated (designated) striped bass spawning area, it does lie within an area expected to be important for larval drift (Nick Carter, MDNR, August 1997). Because the proposed site may cause substantial alterations in hydrodynamics (Moffatt and Nichol 1997), potential significant alterations in regional fish larval distributions could occur. The magnitude of the potential effects is unknown at this time and would have to be confirmed with further modeling.

Site 4B/4B-R

Site 4B is generally located in an area that has the potential to support various lifestages of commercially important species. In terms of shellfish, this site is located too far to the north to support soft shell clams and oysters except in extreme prolonged drought conditions (Chris Judy, MDNR, August 1997). Sites 4B and 4B-R support a relatively productive blue crab harvest throughout the summer (Daniel Beck, BWA, September 1997). Sites 4B and 4B-R were not identified as an important drift netting area, and (although the depths would support it) no pound nets are currently set near Pooles (Daniel Beck, BWA, September 1997). Portions of Site 4B that lie within the APG controlled area (boundary) would be off limits to commercial harvesting when the area is closed.

Most of the finfish species listed above as commercially important use the general vicinity of Sites 4B/4B-R during some portion of their lifestage. White perch use the area around Pooles Island for spawning. The adults of striped bass, white perch, herring, and the spot, croaker, weakfish family also are generally distributed in this area (Funderburk et al. 1991). However, of more importance is that this area is considered as a nursery area for all of these species and as such has the potential to be important to the overall commercial fishery of the upper Bay. Because the proposed configuration of Site 4B includes a large area in the quieter waters west of Pooles Island it is an important nursery area for the commercial species being considered in this investigation. Although the site lies wholly outside of the regulated (designated) striped bass spawning area, it does lie within an area expected to be important for larval drift (Nick Carter, MDNR, August 1997). Because the proposed Sites 4B/4B-R may cause substantial alterations in hydrodynamics (Moffatt and Nichol 1997), potential significant alterations in regional fish larval distributions could occur. The magnitude of the potential effects is unknown at this time and would have to be confirmed with further modeling.

7.2.4 SAV and Shallow Water Habitat

SAV is important to the ecosystem of the Chesapeake Bay. It provides food and shelter to many animal species, absorbs nutrients, produces oxygen, and reduces wave energy, thereby helping to minimize erosion and decrease water turbidity. SAV historically covered large portions of the Bay; however, SAV communities suffered a steep decline in the late 1960s and 1970s (MES 1997a). Estimated historical SAV distributions range upward from 100,000 hectares or more baywide. Aerial surveys (Orth et al. 1992) had placed the approximate coverage of Chesapeake SAV at 24,296 hectares. Baywide SAV coverage and density have increased in recent years; however, recovery rates have not been consistent throughout the Bay (Orth et al. 1994). The presence of SAV is limited to shallow water, usually less than 2 meters in depth, due to light availability requirements (Batiuk et al. 1992).

Shallow water habitat has been defined by the EPA as water not more than four meters below mean low water (EPA 1997). In the upper Bay, the photic zone is two meters or less due to the high levels of turbidity caused by river inputs. Shallow water habitat in the upper Bay is used by many wildlife species for specific life requisites. Many wildlife species use shallow water habitats exclusively because life requisites can not be met in deeper portions of the Bay.

Shallow water areas provide nursery grounds for certain fish species, hunting and foraging opportunities for waterfowl and predatory fish, and resting areas for certain species of waterfowl. These areas also provide fishing, hunting, wildlife observation, and other recreational opportunities for people. As mentioned above, SAV requires shallow water (i.e., water two meters deep or less).

Sites 1, 2, and 3

Water depths at Sites 1, 2, and 3 are too deep to support SAV populations and therefore this resource is not expected to be present in these sites. Also, the depth of the majority of these sites (>4 meters) is not considered to be shallow enough to provide shallow water habitat functions.

Site 4A

SAV has been documented to exist in the general area of Site 4A, but not immediately within the currently proposed boundaries of this site. Common elodea (*Elodea canadensis*), Eurasian watermilfoil (*Myriophyllum spicatum*), coontail (*Ceratophyllum demersum*), and wild celery (*Vallisneria americana*) were found in the Gunpowder River (west of Site 4A) and Eurasian water milfoil was found in Worton Creek (east of Site 4A) (Orth et al. 1996). In 1996, APG verified the presence of the following SAV species in the Gunpowder River and adjacent to Pooles Island: common elodea, Eurasian water milfoil, naids (*Najas gracillima*), muskgrass (*Nitella flexilis*), curly pondweed (*Potamogeton crispus*), redhead grass (*Potamogeton perfoliatus*), wild celery, and horned pondweed (*Zannichellia palustris*) (MES 1997a). APG has established a study plot in the eastern cove of Pooles Island and has observed wild celery, redhead grass, slender pondweed, and horned pondweed (APG 1997).

The water depths of this site are not considered to be shallow enough to provide shallow water habitat functions.

Site 4B/4B-R

SAV has been documented to exist on the south east side of Pooles Island. The Maryland Tidal Wetland Inventory map of Pooles Island delineated two areas of submerged aquatic vegetation on the west side of Pooles Island. This map also depicted two areas of SAV interior to the Island (DNR Undated). SAV has not been confirmed to exist within these interior ponds or to the west of Pooles Island (Wampler 1997b). APG monitors the shallow water areas around Pooles Island for SAV and water quality. A station has been located on the south east side of the Island and SAV has been observed during 1996 and 1997. The species observed and the approximate size of beds are as follows: wild celery (55 m^2), redhead grass (16 m^2), slender pond weed (2 m^2), and horned pond weed (30 m^2) (APG 1997). The near shore areas of this site provide shallow water habitat functions for SAV, waterfowl, and fisheries. Since Site 4B is within the same general area of the Bay as Site 4A, the same regional observations of SAV apply to Site 4B.

The shallow water areas adjacent to Pooles Island are among the habitat types recommended to be protected by the Chesapeake Bay Program's SAV restoration goals (CBP 1995). Tier I habitat exists in those areas of 4B that currently support SAV populations and/or have been documented to support SAV populations anytime since 1971. Tier II habitat (shallow water habitat to one meter in depth) and Tier III habitat (shallow water habitat to two meters in depth) also exists within the boundaries of Site 4B. The Tier I, II, and III habitat types present in Site 4B warrant protection as recommended by the Chesapeake Bay Program.

The alternative alignment, 4B-R, is located in deeper water south of Pooles Island. SAV is not expected to be present in this configuration due to water depths. However, all of the previously mentioned reports of SAV in the region are relevant. The water depths of this site are not considered to be shallow enough to provide shallow water habitat functions.

7.2.5 Waterfowl Use Areas

The Chesapeake Bay supports a diverse group of waterbird species. Waterfowl, shore and marsh birds, and colonial waterbirds are present in the upper Bay region. The Bay is part of the Eastern flyway and is frequented by both resident and migratory species/individuals. Based upon species-specific life requisites, various areas of the Bay are used by various birds. For example dabbling ducks use shallow areas of the Bay (i.e., coves and other near-shore areas) while diving ducks can utilize deeper main-stem sites. The open-water of the Bay provides food and forage opportunities as well as rafting (resting) opportunities.

The upper portion of the Chesapeake Bay historically has been the wintering grounds for approximately 23 percent of the Atlantic migratory waterfowl (Stewart 1962). Dabbling ducks represent the most commonly encountered type of waterfowl located in the upper portion of the Chesapeake Bay (north of the Bay Bridge) (Stewart 1962). Limited use is anticipated for Site Nos. 1 through 3, with considerable use expected for Sites 4A and 4B adjacent and near Pooles Island due to the presence of more complex habitat. A list of waterfowl, shore and marsh birds, and colonial waterbird species that are known to exist in the upper Bay is provided in EA 1997. Waterfowl, in particular, are a valued commercial and recreational resource in Chesapeake Bay due to the long history of game hunting in the region. Waterfowl expected to occur north of the Bay Bridge within the locale that includes the five proposed project sites are provided in EA 1997.

<u>*Sites 1, 2, and 3*</u>

Due to the depths of these sites and the abundance of open water of depths greater than 2 m in the mainstem Chesapeake Bay, only incidental occurrences of waterfowl are expected at these sites. Deep water areas, such as these, may be utilized for staging (rafting) and resting.

<u>*Site 4A*</u>

Pooles Island and the immediate vicinity are recognized as an important waterfowl use area. Although the entire area may not be utilized by waterfowl, the proposed placement sites closest to Pooles are utilized to some extent as feeding and staging areas.

Site 4B/4B-R

Pooles Island has been identified as a significant waterfowl site (NOAA 1996). The adjacent shallow waters of Pooles Island are heavily used by waterfowl and other waterbirds. Waterfowl also use the inland ponds; northern shovelers (*Anas clypeata*) were observed in one of the ponds during the field investigation 29 August 1997. APG personnel have documented that waterfowl utilize the cover along the eastern side of the island as a winter resting spot.

During the spring, hundreds of waterbirds can be observed fishing the shallow waters off the shore of Pooles Island (Wampler 1997b). In addition, a great blue heron rookery is present on the southern portion of the Island. This is currently the largest heron rookery in Maryland (Wampler 1997a). A nest count of the heron rookery performed in May of 1997 reached a total of 1,448 nests (Wampler 1997a).

Due to the water depth of the alternative alignment, 4B-R, waterfowl abundances are expected to be less than those on the island. However, the nearby feeding areas may attract more waterfowl to the site than would occur at other open water sites.

7.2.6 Terrestrial Habitats and Resources

Terrestrial habitats, non-tidal wetlands and uplands (e.g., woodlands, meadows, old fields, etc.), in the upper Bay region provide breeding, nesting, foraging, and refuge opportunities for terrestrial wildlife. These habitat types are located within shoreline (mainland) areas and the islands of the Bay. Terrestrial areas are important habitats for terrestrial wildlife because these areas provide many wildlife species life requisites that can not be fulfilled elsewhere in the region. Island habitats (isolated from development and other infringements) are important refuges for many species.

7.2.6.1 Wetlands

Wetland areas are valuable habitat for various wildlife species, providing areas for wildlife species to live, breed, and feed (Mitsch and Gosslelink 1993). Wetlands are given various designations based upon their type. The prominent wetland types of the Upper Chesapeake Bay include estuarine and palustrine. Estuarine wetlands include deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partially obstructed, or sporadic access to the open ocean. Estuarine wetlands include aquatic beds, tidal flats, emergent wetlands, scrub-shrub wetlands, and forested wetlands. Palustrine wetlands include all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5 percent. Palustrine wetlands include both tidal and non-tidal emergent wetlands, scrub-shrub wetlands, and forested wetlands. The boundary between wetland and deepwater habitat in the estuarine wetland system coincides with the elevation of extreme low water of spring tide; permanently flooded areas are considered to be deepwater habitats. The boundary between wetland and deepwater habitat in the palustrine system lies at a depth of 2 m below low water (Cowardin et al. 1979).

Sites 1, 2, and 3

Wetlands are not present at these sites. These are completely submerged and deeper than the deep water boundary set at two meters (Cowardin et al. 1979).

Site 4A

Wetlands are not present at this site; however, sub-tidal wetland areas are present in the near-water areas immediately adjacent to Pooles Island. Additionally, inter-tidal wetlands are present along the shoreline of Pooles Island and possibly through the center of the Island. The emergent wetlands of Pooles Island are co-dominated by common reed (*Phragmites australis*) and by saltmarsh cordgrass (*Spartina alterniflora*).

Site 4B/4B-R

Pooles Island and the adjacent near-water area supports both palustrine and estuarine wetland types. Pooles Island has forested, scrub-shrub, emergent marsh, and aquatic bed wetlands. Vernal pools occur in the northern wooded portion of the Island. The dominant plant species present within the Pooles Island wetlands include common reed, saltmarsh cordgrass, red maple (*Acer rubrum*), and Juncus species. The adjacent near-water areas support sub-tidal wetland areas with wild celery, redhead grass, slender pond weed, and horned pond weed (APG 1997).

The alternative alignment, 4B-R, is located in deeper water south of Pooles Island. Wetlands areas are not present at this site. The site is completely submerged and is deeper than the deep water boundary set at two meters (Cowardin et al. 1979).

7.2.6.2 Forests and Upland Vegetation

Forests and upland vegetation within the Upper Chesapeake Bay region may be found on islands in the Bay and along the mainland shoreline of the Bay. Plant species tolerant of Bay conditions (i.e., extreme exposure, salinity, frequent to occasional inundation) are present. Common upland plant species of the Bay region include sweet gum (Liquidambar styraciflua), tulip poplar (*Liriodendron tulipifera*), red maple, black cherry (*Prunus serotina*), sassafras (*Sassafras albidum)*, loblolly pine (*Pinus taeda*), marsh elder (*Iva frutescens*), and groundsel tree (*Baccharis halimifolia*).

Sites 1, 2, and 3

These sites are submerged; therefore, this resource (forest and upland vegetation) is not present.

Site 4A

This site is submerged; therefore, this resource, forest and upland vegetation, is not present. However, upland vegetation is present along the shoreline of Pooles Island.

Site 4B/4B-R

Pooles Island is almost completely vegetated. Both the southern and the northern portions of the Island are wooded; seventy five percent of the island is wooded. The remaining portion of the Island is an emergent marsh co-dominated by common reed and saltmarsh cordgrass. Woody species within the wooded areas include sweet gum, tulip poplar, red maple, sassafras, persimmon (*Diospyrus virginiana*), black cherry, black walnut (*Juglans nigra*), black locust (*Robinia pseudoacacia*), willow oak (*Quercus phellos*), mocker nut hickory (*Carya tomentosa*), black gum (*Nyssa sylvatica*), basswood (*Tilia americana*), flowering dogwood (*Cornus florida*), Virginia creeper (*Parthenocissus quinquefolia*), trumpet creeper (*Campsis radicans*), poison ivy (*Toxicodendron radicans*), fox grape (*Vitus labrusca*), and Japanese honey suckle (*Lonicera japonica*) (DeRoia 1997a, Gill 1993, observations by EA 1997).

The alternative alignment, 4B-R, is located in deeper water south of Pooles Island and is completely submerged; therefore, forest and upland vegetation is not present at this site (4B-R).

7.2.6.3 *Terrestrial Wildlife*

Terrestrial wildlife is present within the Upper Chesapeake Bay on islands and along the shoreline of the mainland. Terrestrial wildlife species in the upper Bay include mammals, reptiles, amphibians, birds, and invertebrates. A list of terrestrial wildlife that observed or expected to occur in the project area (specifically on Pooles Island) is provided in EA 1997.

Sites 1, 2, and 3

This site is submerged and does not support terrestrial wildlife.

Site 4A

This site is submerged and does not support terrestrial wildlife; however, neighboring Pooles Island has a diverse terrestrial wildlife population.

Site 4B/4B-R

Pooles Island has a variety of terrestrial wildlife. It is the site of a large great blue heron (*Ardea herodius*) colony and the site of an active bald eagle (*Haliaeetus leucocephalus*) nest. Pooles Island is also a stop-over area for neo-tropical migrants such as red-eyed vireo (*Vireo olivaceus*) and scarlet tanager (*Piranga olivacea*) (Wampler 1997b). Eastern box turtle (*Terrapene carolina carolina*), and eastern mud turtle (*Kinosternon subrubrum subrubrum*) have been observed on Pooles Island, while Fowler's toad (*Bufo woodhousii fowleri*), American toad (*Bufo americana*), and southern leopard frog (*Rana utricularia*) are expected to occur in the wetland and the woodland habitats on the Island (DeRoia 1997b). Wildlife that were observed during the field investigation 29 August 1997 include white-tailed deer (*Odocoileus virginianus*), otter (*Enhydra lutris*), great blue heron, bald eagle, osprey (*Pandion haliaetus*), ruby-throated hummingbird (*Archilochus colubris*), northern water snake (*Nerodia sipedon sipedon*), black snake (*Elaphe obsoleta obsoleta*), and copper-head (*Agkistrodon contortrix*).

The alternative alignment, 4B-R, is located in deeper water south of Pooles Island and therefore does not support any terrestrial wildlife.

7.2.7 Rare, Threatened, and Endangered Species (RTE)

The presence of rare, threatened, and endangered species and their habitats is an important consideration for any development project. The occurrence of endangered species within a project site could potentially impact or exclude its potential use, particularly if the sensitive habitats are identified within a project site.

NMFS, USFWS, and MDNR (Heritage program) were consulted regarding the status of RTE species and potential critical habitats within the project site. No response has yet been received from Heritage (at the time of this section). However, USFWS and NMFS personally communicated their concerns over two endangered species that potentially occur in the area. Although previously only reported sporadically at the Bay Bridge, 10 shortnose sturgeon have been identified in pound nets in Cecil, Baltimore, and Kent counties within the past year (Tim Goodger, NMFS, August 1997 and John Nichols, NMFS, September 1997) (landings maps provided in EA 1997). One of these specimens was taken near HMI in 1996. A recent increase in reports may be related to the bounty system initiated in 1996 on all sturgeon caught in the Bay (Rosenberg 1997). Due to the sparse information about the life history, habitat preferences, and distributions in the Upper Chesapeake Bay, it is impossible to know if shortnose sturgeon in the area are part of the Delaware population or not (Rosenberg 1997). Therefore, NOAA cannot (at this time) accurately determine the distribution of shortnose sturgeon in the Bay and believe that it may be present in the vicinity of the approach channels and dredged material disposal operations (Rosenberg 1997).

NMFS recently assigned the status of "present" to shortnose sturgeon in Chesapeake Bay (John Nichols, NMFS, September 1997). Resource agents can not preclude the shortnose sturgeon from occurring at the proposed project sites because there is not enough currently known about their distributions and habitat utilization with in the Bay (John Gill, USFWS, August 1997 and Tim Goodger, NMFS, August 1997). Because of the uncertainty, NOAA (NMFS) will require that shortnose sturgeon studies be conducted as part of a Section 7 consultation of the Endangered Species Act for all proposed Bay construction projects (John Nichols, NMFS, September 1997).

Studies of shortnose sturgeon (if performed) may also provide information to help determine the status of Atlantic sturgeon (which is proposed for listing as a threatened species). The USFWS is conducting studies in the cobble areas around Pooles Island in an attempt to determine if this unique mainstem habitat is an important area or critical habitat for shortnose sturgeon (John Gill, USFWS, Annapolis Office, August 1997).

The only other endangered species of concern identified near any proposed site is a bald eagle nest on Pooles Island (John Gill, USFWS, August 1997). This species would only be a concern at Site No. 4B.

7.3 Social/Public Welfare Resources

In addition to natural resources, there are additional elements of the "human environment" to which we attach value. These have been broadly classified as social/welfare resources and are addressed in the following sections.

7.3.1 Archaeological/Historic Resources

All designated historical/archaeological sites and sites of potential historical/archaeological significance on public lands are protected by law (i.e., SHPA, A106). Prior to implementation of all public projects, the law requires investigation to identify presence of historical/archaeological sites. The investigation of these resources for this prefeasibility report is, therefore, cursory. Any area that is seriously considered for a dredged material placement site will require a Phase I Archaeological investigation that is reviewed by the Maryland State Historic Preservation Officer (SHPO). The SHPO was contacted for this effort (EA 1997). In her reply, reference was made to the potential for historic resources on Pooles Island and the efforts undertaken at APG to document them. The resources of the SHPA library were offered for our use, as necessary.

Sites 1, 2, and 3

No historic submarine archaeological investigations were identified for these open water sites based upon a review of submarine investigations done by Ocean Surveys (1993) as part of the investigations for Area "G-West." The closest investigation was conducted for the proposed widening of the Brewerton Channel Eastern Extension site (south of Site 2) as part of the EIS for the proposed widening (USACE—Baltimore 1997). The investigation found no potential submerged resources. A cursory review of the nautical chart indicated that no shipwrecks or unidentified submerged obstructions are charted for the areas that include Sites 1, 2, and 3. No additional information on archaeological or historic resources for these sites was obtained.

Sites 4A, 4B, 4B-R

In 1992, a study was conducted by Ocean Surveys, Inc. (1993) to investigate submerged cultural resources within a project site designated "G-West," located approximately 1,300 ft east of Pooles Island. Significant cultural resources included any material remains of human activity that were eligible for inclusion on the National Register of Historic Places (Ocean Surveys, Inc. 1993). Twelve documented shipwrecks and 11 reported obstructions were included in the Maryland Historical Trust shipwreck and submerged obstructions data list, but this list was referenced as "Pooles Island and Vicinity," encompassing G-West. Shipwrecks on this list are included in EA 1997. Reported obstructions included submerged wrecks, ruins, visible wrecks, and other obstructions (Ocean Surveys, Inc. 1993). However, for site G-West, none of the four principal target locations identified during the 1993 survey appeared to possess characteristics making them eligible for nomination to the National Register of Historic Places (Ocean Surveys, Inc. 1993). No further archaeological investigation was recommended for the "G-West" site.

In a draft environmental assessment of the Upper Chesapeake Bay, two dredged material placement sites were assessed in the area surrounding Pooles Island (MES 1997a). The sites designated in the environmental assessment as Original G-East and Original Site 92 are in the vicinity of the currently designated Sites 4A and 4B, respectively, at Pooles Island. Two submerged targets exhibiting shipwreck characteristics were identified in Site 92 and in an area immediately adjacent to the original G-East location; however, when the northern boundary of G-East was relocated further south, this target was no longer in the project site. Further investigation of the target within Site 92 is ongoing (MES 1997a). The National Register of Historic Places does not list any known submerged historical/archaeological sites in the G-East and Site 92 project sites (MES 1997a).

A visual nautical map survey by EA personnel (NOAA chart #12278, NAD83) for submerged obstructions or shipwrecks in the approximate area of Sites 4A, 4B, and 4B-R revealed one submerged obstruction at Site 4A and two shipwrecks at 4B. In addition, another shipwreck was noted just outside of northern boundary of proposed Site 4B near the Pooles Island lighthouse. No shipwrecks or obstructions of interest were found for Site 4B-R. "Shipwrecks on the Chesapeake" (Shomette 1982) was also reviewed for shipwreck information.

The oldest lighthouse in the SOM is on Pooles Island (Kaltenbacher 1996). The lighthouse was constructed in 1825 to ensure safe navigation in the Bay (Kaltenbacher 1996). The SHPO has determined that the lighthouse is eligible for listing in the National Register of Historic Places (Kaltenbacher 1996). Any increase in the size or configuration of the island (by the addition of dredged material) is subject to the National Historic Preservation Act and must be reviewed for impact by the SHPO, the A-106 process. In addition to the lighthouse, it has been reported that there are approximately five range towers on the island that need to be evaluated for their eligibility to the National Register (David Blick, APG, August 1997, personal communication to Mike Gilbert).

In his memo to Mike Gilbert, David Blick stated that:

Prior to the initiation of any federal activity that may affect these resources, APG will need to conduct the Section 106 review process and coordinate with the State Historic Preservation Office Advisory Council on Historic Preservation (IAW with 36 CFR Part 800). This is accomplished through the NEPA documentation process.

The Cultural Resource Program has undertaken a project to restore and stabilize the Pooles Island lighthouse (Kaltenbacher 1996). A cleaning phase of this restoration project occurred in late October 1995. Many structural aspects were completed in 1996, including mortar repair performed by the United States Coast Guard Reserve Lighthouse Maintenance Unit (Kaltenbacher 1996). Granite rubble in front of an observation tower on Pooles Island could indicate the remains of the old oilhouse (Kaltenbacher 1996).

Several suspected archeological sites were excavated in 1995 on Pooles Island and unearthed prehistoric Native American artifacts, including oyster shell middens and various lithic, ceramic, and organic artifacts, thus supporting the theory that various Indian tribes fished and hunted on the island, and possibly had small settlements there (Kaltenbacher 1996).

A solitary grave stone exists on Pooles Island with a date of 1855 and an inscription of the story of two brothers, Captains Elijah and James Williams who were lost and died in a snowstorm near Pooles Island (Kaltenbacher 1996).

A map depicting locations of documented submerged obstructions and historical structures is provided as Figure 7-3.

7.3.2 Recreational Value

The Upper Chesapeake Bay is heavily used for recreational activities, including bird watching, boating, swimming, and fishing. For the purposes of this investigation, fishing activities were considered separately from all other recreational activities. No specific recreational studies, aside from fishing activity, were identified for the upper Bay. Within the region, however, there are abundant marinas and boat launches, particularly on the Middle, Magothy, Bush, and Gunpowder Rivers and in Rock Hall. The majority of recreational boating activities would take place near shore. This is also true of swimming and bird watching. Sailing and cruising on larger vessels would be restricted to deeper waters. Portions of all potential sites would accommodate these latter two activities.

Sites 1 and 3

Although not near any shoreline areas, these sites are close enough to significant boating and marina areas that at least moderate recreational use can be expected.

Site 2

This site is far enough away from both the shoreline areas and the marinas that it probably has the least recreational value of any of the sites.

Sites 4A, 4B, 4B-R

Due to the high concentration of birds and nesting activities on Pooles Island, these sites have the highest potential for birdwatching except for restrictions on access at APG. Because much of the area that includes Site 4B is closed to public access due to activities at APG, the recreational opportunities for this site are probably less than that of 4A or 4B-R. Sites 4A, 4B, and 4B-R lie within areas that probably see the highest recreational boating use due to the proximity to the mouth of the Bush and Gunpowder Rivers.

7.3.3 Aesthetics and Noise

Aesthetics and noise are two public concerns during dredging and dredged material placement activities. An increase in noise and an unquantifiable, slight increase in air emissions is projected as a result of engine exhaust from dredges and from tugs involved in dredged material placement activities (MES 1997a). This factor is of most concern if the site is near a population center. Turbidity is expected to increase following the placement of dredged material at any of the proposed sites, but will generally be a short-term, localized phenomenon. Another potential effect is a visual change in the viewshed. Although such a change may be of concern to some homeowners, views are not considered a property right under state law.

All Sites

All of the proposed placement sites are greater than 0.5 mi away from any population centers. The short-term, localized turbidity increases would be similar for all sites considered, although slight site-to-site differences can be expected based upon site-specific hydrodynamics and final site configurations. Potential changes in the viewshed are expected to be similar at all sites. Due to the proximity to Tolchester Beach, construction of an island at Site 1 might be considered, by some, to have an aesthetic impact.

7.3.4 Navigation and Commerce

The USACE has the mission and authority to maintain navigation channels in the interest of safe navigation, and to do so in a thorough manner to ensure compliance with established dimensions and consistency with authorized project dimensions (MES 1994).

Navigation channels in the northern Chesapeake Bay are routinely dredged to permit vessel passage (Halka et al. 1991). The C&D Canal northern channels in the upper Bay are a major shipping route for access to the Port of Baltimore (MES 1997a). The C&D Canal and its connecting channels also provide access to Ports of Philadelphia, Wilmington, and New York as well as the European trade routes (MES 1997a). Channels located in the vicinity of the proposed containment islands (including the C&D Canal approach channel, the Tolchester Channel, the Swan Point Channel, and the Brewerton Channel) are discussed below and presented in Figure 3-1. Physical obstruction of these channels would eliminate their use for navigation or result in a hazard to navigation. Disturbance of currents in these channels could result in more difficult operating conditions than exist at present and which, therefore, could potentially adversely impact navigational safety. Changes in these channels could increase the potential for marine vessel collisions or groundings which could result in environmental disaster.

Site 1

This site lies more than 1 mi outside of charted navigation channels.

Site 2

The Tolchester Channel is located east of Site 2, and the Brewerton Channel is located southwest of this site. Some potential alignments of this site fall within approximately 1,000 ft of the Tolchester Channel. The hydrodynamics of an island placed at this location could impact navigation due to effects on currents that it may create.

Site 3

The Swan Point Channel is located immediately east of Site 3, northeast of the site. The Brewerton and Tolchester channels are approximately 1.5 mi or greater north of the site.

Site 4A

The C&D Approach Channel is located east of and adjacent to Site 4A. A portion of this site would lie within the West Sailing Course which is utilized by tug boats with lightly loaded or empty barges (MES 1997a). The hydrodynamics of an island placed at this location could impact navigation by the effects on currents that it is expected to create.

Site 4B/4B-R

The C&D Approach Channel and West Sailing Course are located in the vicinity of the site, but no proposed configuration would lie within either channel. However, the hydrodynamics of an island placed at either 4B or 4B-R may increase cross-currents in the vicinity of the Western Sailing Course. The extent to which these currents may impact navigation would have to be examined more closely in the next phase of the project.

7.3.5 Fossil Shell/Mining Resources

Fossil oyster shell dredging was first recorded in the upper Bay in 1960 (MES 1997a). The current estimate for the total acreage dredged since 1960 is 1,075 acres (MES 1997a). Fossil oyster shells found in lumps or reefs on the Bay floor are dredged for use in the State's oyster propagation program (MDNR 1987). The program is designed to renovate natural oyster bars and provide a hard, clean substrate upon which oyster larvae can attach and grow (MDNR 1987). Locations of currently permitted and previously permitted fossil oyster shell dredging areas are provided in Figure 7-4. Previously permitted areas can be re-permitted for future use.

Sites 2, 3, 4B, and 4B-R

No fossil shell resources have been found associated with these sites.

Site 1 and 4A

In 1987 the SOM proposed to continue dredging fossil oyster shell from several sites in the Upper Chesapeake Bay in the vicinity of Hart-Miller and Pooles Island (MDNR 1987). There are currently three permitted sites for fossil oyster shell dredging in the upper Bay, and these sites are located southeast of HMI, south of Pooles Island, and west of the C&D approach channel (MES 1997a) (Figure 7-4). There are also six previously permitted sites in the same general vicinity of upper Bay that could be re-permitted in the future and used for fossil oyster shell dredging. The Environmental Assessment of G-East and Site 92 (MES 1997a) states that "Current permits allow 4,641 acres (18.8 mcm) to be dredged, of which 885 acres (3.6 mcm) has been dredged to date (Judy, MDNR, January 1997, personal communication)."

7.3.6 CERCLA/UXO Potential

APG is on the National Priority List (NPL) of hazardous waste sites. As such, any activities on the site must be conducted through the framework of CERCLA. This poses a major liability to any potential development project. For this project, only Sites 4A and 4B would have this potential problem. These sites, too, have the potential for containing UXO. UXO within a site would be costly to construction and a large liability. Site 4B-R is outside of APG boundary and, therefore, free from the CERCLA liability (as presently defined). However, APG staff have indicated that the area south of Pooles Island was used as a target and the UXO potential at 4B-R is very high. No other proposed sites have the potential for either of these problems.

7.4 Environmental Ratings

The following Section details the numeric evaluation and individual site results for each environmental parameter of concern. Parameter weighting and final numerical results are also discussed.

7.4.1 Numerical Evaluation and Matrix

Base evaluations for each parameter have been summarized in the matrix presented as Table 7-5. Weighting factors were assigned to each evaluation and are presented with the weighted results in Table 7-6. For the purposes of evaluation, Sites 3 and 3S (the submerged alternative) were considered to be essentially the same, although 3S is slightly larger. Sites 4B and 4B-R shared the same existing conditions information, but for evaluation purposes, the sites were separated to show the effect that detaching the site from Pooles Island would have on the environmental assessment. The alternate location for Site 2 is not evaluated here due to a lack of information gathered at the time of section preparation.

7.4.1.1 Water Quality

The evaluation of this parameter was based upon both existing and predicted conditions of the site. For existing conditions, hypoxia potential at each site in the summer constituted the base evaluation. Potential future effects on the gyre circulation were considered, but because the predicted conditions for the gyre could not be completely determined at the time of section preparation, the evaluation reflects hypoxia potential only. If the effects on the gyre are predicted, it will likely only influence the evaluation at Site 1 (lowering the overall totals). If a site was prone to oxygen depletion it was assigned a positive evaluation (+1), indicating higher feasibility for construction of a dredged material placement facility. Only Sites 2 and 3 showed evidence of hypoxia, so all other sites were evaluated as -1 (Table 7-5). This parameter was given a weighting factor of 2 (Table 7-6) based upon the Master Plan variable "wq" (MPA 1989).

7.4.1.2 Salinity

Preliminary assessments of the effects of island construction on regional salinity (Chapter 5) indicate that a minor increase (0.5 ppt) may occur in some reaches (near Stations 4A, 4B and 4B-R). This result would have to be confirmed with further modeling. Potential alterations to the salt wedge as a result of island construction can not be predicted without three-dimensional modeling. For these reasons, all sites received an evaluation of zero because more information is necessary in order to assess the potential effects. Salinity received a weight of 4 based upon working group deliberations.

7.4.1.3 Hydrodynamic Effects

The studies supporting the evaluations for this category are summarized in Chapter 5 and Moffatt and Nichol (1997). This parameter includes only potential hydrodynamic effects to erosion and sedimentation properties or effects of increased localized currents on benthic habitat. Note that erosion/sedimentation modeling was not complete at the time that this section was prepared. Since that time, modeling has been completed but a re-evaluation of the environmental effects will not be made until 3-D modeling is completed. Effects of hydrodynamics to navigation are evaluated separately (below). Potential effects on larval fish distribution are also handled separately. If changes in current velocity due to island configuration or placement were expected to increase erosion or impede the natural distributions of SAV or other organisms, the site received an evaluation of -1. If no such hydrodynamic impacts were expected, the site received a value of +1. The hydrodynamics of Sites 1, 2, and 3 are not expected to have any substantial effects on erosion or sessile biota, although locally higher currents are expected around each island. The hydrodynamic alterations resulting from constructing a placement facility at Site 4A or 4B may constrict the mainstem to the point that current velocities could be substantially increased. For example, hydrodynamic modeling of Site 4A reflected a substantial current velocity change relative to ambient conditions (Chapter 5 and Moffatt and Nichol 1997). Because velocities are increased along the Eastern Shore, which also increases erosion potential, Site 4A was assigned a value of -1. Site 4B/4B-R also received a value of -1 because the increased currents predicted for these sites would train fast-moving water into sensitive shallow water areas known to support SAV (which prefer slower currents) and would potentially effect the gyre circulation south of Pooles Island. Physical hydrodynamics received a weighting of 4 based upon best professional judgement. The numeric evaluations in this category may be influenced by future modeling results, particularly the results of sedimentation modeling. Evaluations are, therefore, tentative at the time of section preparation.

7.4.1.4 Sediment Quality

Evaluations for this parameter were based upon current sediment quality conditions as defined by the NOEL and PEL limits for trace metal concentrations measured (Eskin et al. 1994). Sites with sediment concentrations of at least one target compound of concern exceeding the PEL received an evaluation of +1. Sites with metal concentrations exceeding the NOEL but not the PEL received an evaluation of 0. Sites where all parameters had trace metal concentrations below the NOEL would be evaluated as -1, although no sites fell into this category. Based upon their respective trace metal concentrations, Sites 1, 2, and 4B/4B-R received numeric evaluations of +1, and Sites 3 and 4A received zeros. Sediment quality received a weighting of 2 after the "sub" variable in the Master Plan (MPA 1989).

7.4.1.5 Benthic Community and Habitat

Screening-level information was used to calculate a Benthic-Index of Biological Integrity (B-IBI) (Weisberg et al. 1997). The B-IBI determines the degree to which a site approximates, deviates slightly, or deviates strongly from conditions at reference locations. Sites with an average Benthic-IBI score of <3 were considered stressed and assigned positive evaluation (+1); sites with an average B-IBI ≥3 received a negative evaluation (-1). Based upon screening-level information, Sites 1, 4A, and 4B show little apparent signs of stress, while Sites 2 and 3 show evidence of stress or impairment to the benthic communities (Table 7-5). Impairment at Site Nos 2. and 3 may be caused by naturally occurring hypoxic events during the summer months. A weighting of 2 was assigned to this parameter (Table 7-6) following the "sub" and "wq" weightings of the Master Plan (MPA 1989). It should be noted that construction at Sites 4A, 4B/4B-R, and 2 would require borrowing sand from Site 1 and the immediate vicinity (GBA 1997). This would impact benthic communities and habitat value at the borrow location.

7.4.1.6 Recreational Fishery

This parameter was evaluated based upon anecdotal information from charter boat fishermen and on observations of recreational fishing activity made during the EA trip to Poole's Island and during sediment collections. Site 1, due to its proximity to the fish havens and the usage indicated by the MCBA representative (Lawrence Thomas, MCBA, August 1997), and Site 4B (due to high relief bottom that occurs off of the western shore of Poole's Island) were considered to have the best value for recreational fishing and were evaluated as -1. Site 2 was not identified as an important recreational fishing site by any means and received a +1. Site 4A was identified by Lawrence Thomas as important to striped bass fishing and received a -1. Site 3, although near sites identified for high recreational fish use, did not appear to support substantial recreational fishing. Due to this ambiguity, Site 3 was evaluated as zero. Site 4B-R was not identified as, or observed to be, an important recreational fishing area, and was assigned a numeric evaluation of +1. A weighting of 4 was assigned to this parameter following "fsh" in the Master Plan, with input from MES (MPA 1989).

7.4.1.7 Commercial Fish and Shellfish

Sites that were located within or would potentially impact known staging, fishing, or overwintering areas, or sites that were located in areas with favorable substrate conditions for the key species identified in Section 7.1, were given a negative rating with respect to commercial fish and shellfish. Sites 1, 2, and 3 were identified as productive crabbing areas in fall/spring and drift net areas (for striped bass and white perch) in winter (Daniel Beck, BWA, September 1997 and Larry Simms, MWA, October 1997). These sites received an evaluation of -1. Due to their usefulness as either staging areas, summer refuge, or known uses for commercial fish or crabbing, Sites 4A, 4B, and 4B-R were also evaluated as potentially important for commercial fish or shellfish. This parameter was weighted as 4 following "slf" from the Master Plan (MPA 1989).

7.4.1.8 Finfish Spawning and Rearing

The factor considered for this parameter was restricted to infringement on known critical spawning or rearing areas. Potential hydrodynamic effects on the salt wedge and up-bay migration of marine/high mesohaline species and potential hydrodynamic effects on down-bay migration of early lifestages of fish spawned in freshwater or oligohaline reaches of the upper Bay are included separately as "Larval Transport" (Section 7.4.1.9).

A site that would negatively impact known fish spawning or nursery areas was given a negative evaluation for this parameter. Sites 2 and 3 were not identified as important areas for this parameter and were assigned a numeric evaluation of +1. Site 4A lies within an area known to support various lifestages of commercially important species and received a numeric evaluation of -1. Although Site 1 does not lie directly within an area of critical spawning habitat, it is adjacent to areas known to be important for rearing of white perch and herring species. Site 1, therefore, received a 0. Due to the shallow depths that occur over most portions of the site, Site 4B may be a potentially important spawning/rearing site. Although Site 4B-R is generally deeper than areas associated with nursery habitat, it lies within the general nursery area for several commercially important species. It, therefore, received a -1. A weighting factor of 4 was assigned to this parameter at the request of resource agents.

7.4.1.9 Larval Transport

As a way of predicting potential effects to larval transport, the residence times of suspended particulates were modeled (Chapter 5 and Moffatt & Nichol 1997). Preliminary results of this modeling indicate that slight increases in residence times may be expected as a result of construction of most island configurations. This would have to be confirmed with more in-depth modeling and the significance of the result on larval transport would have to be examined more closely than could be accomplished at the time of section preparation. All sites, therefore, received an evaluation of zero for this parameter at this time. Larval transport received a weight of 6 based upon working group deliberations.

7.4.1.10 SAV and Shallow Water Habitat

The presence of SAV resulted in a negative numeric evaluation (-1) for this attribute. Additionally, shallow water habitat is valuable for many ecological factors and impacts to shallow water habitat, even in the absence of SAV, resulted in a negative evaluation for the SAV and shallow water habitat attribute. Site 4B was the only site at which this parameter received a -1. This resource does not occur at the other sites, so all other sites received a +1. SAV was assigned a weighting of 4 both here and in the Master Plan (MPA 1989).

7.4.1.11 Waterfowl Use

The Bay is used by both migratory water fowl and resident species for a variety of uses. Sites that either fall within, or may negatively impact, known waterfowl use areas were given a negative evaluation (-1) for this parameter. Sites 4A and 4B (adjacent to Pooles Island) were evaluated as -1 for this parameter because the island has been identified as an important waterfowl use area. Because waterfowl also use open water near potential feeding areas for staging/rafting, some occasional use may occur at Sites 1, 2, and 3, and 4B-R. Due to the abundance of open water greater than 2 meters deep in the upper Bay, these sites were not considered to be important to the resource and received an evaluation of +1. Waterfowl were given a weighting of 1 both here and in the Master Plan (MPA 1989).

7.4.1.12 Tidal Wetlands

This category is limited to the Pooles Island area where the possibility of impacting wetlands exists. Sites containing wetlands were given a negative rating relative to the suitability of constructing a dredged material placement site. This resource only occurs at Site 4B, which received a numeric evaluation of -1. Site 4B-R received a "zero" due to the possibility of potential island erosion caused by hydrodynamic effects. Additional modeling information is required to evaluate the potential impact to tidal wetlands. All other sites received a +1. Tidal wetlands received a weighting of 3 following the guidelines in the Master Plan (MPA 1989).

7.4.1.13 Terrestrial Habitat and Wildlife

This category is limited to the Pooles Island area where the possibility of impacting terrestrial habitat and wildlife exists. The only site that has the potential to impact this resource is Site 4B, which received an evaluation of -1. Site 4B-R received a "zero" due to the possibility of potential island erosion created by hydrodynamic effects. Additional modeling information is required to evaluate the potential impact to terrestrial resources. All other sites received a +1. Terrestrial habitats/wildlife received a weighting of 2 following the forest ("for") variable in the Master Plan (MPA 1989).

7.4.1.14 Protected Species (RTE)

The presence or probable presence of a protected species was considered to be negative relative to the feasibility of a dredged material placement site. Because of the potential occurrence of shortnose sturgeon throughout this region, all sites received a numeric evaluation of -1. Site 4B includes the cobble habitat surrounding Poole's Island which may be of more significant habitat value to this species. Site 4B would also involve construction in the vicinity of a bald eagle nest. Protected species were assigned a weighting of 5 for each potential species present resulting in -5 for all sites except Site 4B (which received a -10).

7.4.1.15 Recreational Value

If a proposed site is located in an area that is known to be disproportionately used as a recreation area, the site received a negative evaluation. Normal recreation use intensity would not be considered a negative because most of the Bay is used for recreation. If a site was known to support very limited recreational use compared to the rest of the upper Bay, this site received a +1 for the construction of a dredged material placement site. Due to a lack of quality information for this resource type, Sites 1 and 3 were assigned a value of zero. Site 2, which seemingly had lower recreational potential, was assigned a value of +1. Sites 4A and 4B/4BR, which had a high potential for boat traffic, were assigned a negative evaluation (-1). Recreational value was not evaluated or weighted in the Master Plan. This parameter was assigned a weighting of 2 based upon the economic value of recreational boating to the region.

7.4.1.16 Historic Resources

This resource category was evaluated with caution because any sites that are elected for further consideration must be subjected to formal archaeological investigation. The presence or potential presence of these resources within the boundaries of a proposed site was assigned a negative evaluation. The absence of a historic site was evaluated as positive for development. The only site known or expected to contain cultural or historical resources is Site 4B and it was assigned an evaluation of -1. This parameter combined two factors used in the Master Plan ("arc" and "hst") for a combined weighting of 4 (MPA 1989).

7.4.1.17 Aesthetics and Noise

If a site was located within approximately 0.5 mi of a population center, it was considered to have the potential to negatively impact aesthetics and noise. No sites met this criterion, so all sites (except Site 1) were assigned an evaluation of +1. Due to its proximity to Tolchester Beach, some might consider the island at Site 1 as an aesthetic impact. Site 1 was, therefore, assigned a numeric evaluation of zero. Weighting for this parameter was 2, after "pop" from the Master Plan (MPA 1989).

7.4.1.18 Fossil Shell Mining

Fossil shell mining was viewed as an important resource for the continued production of oysters from the Bay. Therefore, a site that may potentially cover a mapped area of fossil shell would receive a negative evaluation (-1). Fossil shell resources were only currently being mined near Sites 1 and 4A, so these were the only sites that received a -1 for this resource. Fossil shell is not known to occur at Sites 2, 3, 4B, or 4B-R, thus the positive evaluation (+1). Fossil shell mining was assigned a weighting of 2 based upon best professional judgement.

7.4.1.19 CERCLA and Unexploded Ordnance (UXO) Potential

Because unexploded ordnance and CERCLA liabilities would significantly complicate the construction of a containment facility, sites with this potential were rated negative (-1) for this category. Sites 4A, 4B, and 4B-R were the only sites that received a -1 for this parameter, because some portion of their alignments fell within the APG boundary (which is an NPL site) or within the known target areas. Sites 1, 2, and 3 do not involve CERCLA or UXO issues and, therefore, received a numeric evaluation of +1. This parameter was given a combined CERCLA and UXO weighting of 5 based upon best professional judgement.

7.4.1.20 Navigation

Any site that will directly or indirectly hinder commercial navigation, or posed a threat of potential environmental disaster caused by a vessel collision/grounding, was given a negative evaluation (-1). Site 4A includes part of the West Sailing Course and was, therefore, assigned a -1 for this parameter. Site 2 lies very close to two navigation channels and, because of potential hydrodynamic impacts to navigation, received -1 for this parameter. Changes in hydrodynamics at 4B/4B-R are predicted to have some effect on current velocities in the vicinity of the West Sailing Course but the extent to which navigation would be affected will need further investigation. These sites, therefore, received a value of zero. Sites 1 and 3 are not expected to hinder navigation. This parameter was assigned a weighting of 4, based upon best professional judgement and consultations with USACE Baltimore and Philadelphia Districts. Note that sedimentation modeling was not complete at the time that this section was prepared. Since that time, modeling has been completed but a re-evaluation of the environmental effects will not be made until 3-D modeling is completed.

7.4.2 Overall Numerical Evaluation

7.4.2.1 Site 1

Site 1 received a base evaluation of 3 (Table 7-5) and a weighted evaluation of 10 (Table 7-6). Although the site did not have the highest numerical evaluation at this phase of the investigation, no significant limitation was identified within the available information that would discount this site as an option for development. Weighting had no effect on the overall rating of this site.

7.4.2.2 Site 2

Site 2 had the highest numerical evaluation, with a base evaluation of 12 and, weighted evaluation of 30. Based upon environmental considerations, this site would be one of the best for development of a dredged material placement facility.

7.4.2.3 Site 3

Site 3, with base and weighted evaluations of 11 and 30 (respectively) was very similar to Site 2 (with base and weighted evaluations of 12 and 30, respectively). Site 3, therefore, is among the most environmentally suitable sites for development of a placement facility. Site 3, if developed as a submerged site (3S), could have significant beneficial uses as fisheries habitat.

7.4.2.4 Site 4A

Site 4A had a low numeric evaluation compared to the other sites. The base evaluation for this site was -7 and the weighted evaluation was -24. Site No. 4A was not among the best choices for development from an environmental perspective.

7.4.2.5 Sites 4B/4B-R

Site 4B had the lowest numerical evaluation in terms of both base (-12) and weighted (-49) evaluations indicating that it is the poorest choice of the five sites for development of a dredged material placement facility. This site has several significant limitations, including RTE potential, CERCLA/UXO potential, and archaeological/historical resources. By developing a site south of Pooles Island that retains no connection to the island (Site 4B-R), several resource issues diminish, as reflected in the higher numeric evaluation for 4B-R (-2 base evaluation, -13 weighted evaluation).

7.5 Environmental Findings

Note that hydrodynamic modeling was not completed at the time that this section was prepared. Since that time, modeling has been completed but a re-evaluation of the environmental effects will not be made until 3-D modeling is completed.

7.5.1 Site 1

Site 1 may be a viable alternative for placement site development. This site rated behind Sites 2 and 3. Although a feasible location for construction, natural resource issues do exist in this area. The benthic communities at this site exhibit little apparent signs of environmental stress. In addition, the site is located near artificial reef structures that create a fish haven. The site also lies within an area that has been identified as important as a recreational and commercial fishery, and the site is located at the southern end of spawning and nursery grounds for some commercial species. A large portion of Site 1 is currently permitted as a fossil oyster shell dredging area. A long term beneficial use for this site includes terrestrial island habitat creation. The recent occurrence of shortnose sturgeon in the upper Bay region will be a potential permitting issue for this site.

7.5.2 Site 2

Site 2 is one of the least environmentally sensitive alternatives for development of a dredged material containment island. Existing benthic communities at this site exhibited signs of stress which may be attributable to naturally occurring hypoxia during the summer months. Site 2 has a lower recreational fisheries value than several of the other sites and is not a significant nursery area for commercial species. Although one of the least environmentally sensitive sites, hydrodynamic changes created by a containment facility in this area could potentially affect navigational safety in the nearby shipping channels and approach channels to Baltimore Harbor. A long term beneficial use for this site includes terrestrial island habitat creation. The recent occurrence of shortnose sturgeon in the upper Bay region will be a potential permitting issue for this site.

7.5.3 Site 3

Site 3 is one of the least environmentally sensitive alternatives for development of a dredged material containment island. Existing benthic communities at this site exhibited signs of stress which may be attributable to naturally occurring hypoxia during the summer months. Site 3 does have commercial fishery value, predominantly in the winter months. In addition, several large commercial oyster bars (Hodges Bar and Swan Point) are located nearby. A long term beneficial use for this site includes terrestrial island habitat creation. The recent occurrence of shortnose sturgeon in the upper Bay region will be a potential permitting issue for this site.

7.5.4 Site 3S

Site 3S is one of the least environmentally sensitive alternatives for development of a dredged material containment island. Existing benthic communities at this site exhibited signs of stress which may be attributable to naturally occurring hypoxia during the summer months. Site 3S does have commercial fishery value, predominantly in the winter months. In addition, several large commercial oyster bars (Hodges Bar and Swan Point) are located nearby. Once filled, the submerged containment island could be developed into a shallow-water reef fish habitat or an oyster bar, a potentially significant beneficial use. The recent occurrence of shortnose sturgeon in the upper Bay region will be a potential permitting issue for this site.

7.5.5 Site 4A

Site 4A is one of the least suitable sites for development based on environmental evaluations. Benthic communities in the area exhibit little apparent signs of stress. The site potentially supports a various life stages of commercially important species, is an important nursery area for commercial fish species, and supports a significant blue crab fishery. Due to its proximity to Pooles Island, Site 4A is probably used as a feeding and staging area for waterfowl. In addition, Site 4A contains areas previously and currently permitted for fossil oyster shell dredging. Hydrodynamic changes created by a containment facility in this area could potentially affect navigational safety in the nearby shipping channels and approach channels to Baltimore Harbor. Hydrodynamic changes could also potentially influence larval fish transport. The recent occurrence of shortnose sturgeon in the upper Bay region will be a potential permitting issue for this site. A portion of Site 4A lies within Aberdeen Proving Ground (APG), a National Priority List (NPL) hazardous waste site. Due to its proximity of APG, Unexploded Ordnance (UXO) likely exist at this site.

7.5.6 Site 4B

Site 4B is one of the least suitable sites for development based on environmental evaluations. Benthic communities in the area exhibit little apparent signs of stress. The site potentially supports a various life stages of commercially important species, serves as an important spawning area for white perch, and serves as an important nursery area for commercial fish species. Because this Site is attached/abutted to Pooles Island, Site 4B is intensively used by both waterfowl and waterbirds. A large heron rookery is located on the south end of Pooles Island and a bald eagle nest is also located on the island. SAV is present on the east side of Pooles Island and warrants protection as recommended by the Chesapeake Bay Program. Pooles Island also contains historical and archaeological resources, including the oldest lighthouse in the SOM and a native American shell midden. Hydrodynamic changes created by a containment facility in this area could potentially affect navigational safety in the nearby shipping channels and approach channels to Baltimore Harbor. Hydrodynamic changes could also potentially influence larval fish transport in this region. The recent occurrence of shortnose sturgeon in the upper Bay region will be a potential permitting issue for this site. A portion of Site 4B lies within APG, an NPL hazardous waste site. Due to its proximity to APG, UXO likely exists at this site.

7.5.7 Site 4B-R

Site 4B-R is lacks the terrestrial, natural, historical, and archeological resources associated with Pooles Island, and therefore, involves fewer environmental trade-offs than Site 4B. stress. Hydrodynamic changes created by a containment facility in this area could potentially affect navigational safety in the nearby shipping channels and approach channels to Baltimore Harbor. The recent occurrence of shortnose sturgeon in the upper Bay region will be a potential permitting issue for this site. Although Site 4B-R does not lie within APG, due to its close proximity, UXO potentially exists at this site.

Table 7-1 Environmental parameters considered for the Upper Bay Island placement site ranking

Parameter	Factors Considered
Water Quality	•Dissolved Oxygen •Effects on Gyre
Salinity	•Changes to Salt Wedge and regional salinity
Hydrodynamic effects (physical)	•Erosion and sedimentation •Increased currents in critical areas (e.g. SAV beds)
Sediment quality	•Potential toxic effects
Benthic Community and habitat	•Benthic IBI
Recreational Fishery	•Potential Recreational fish utilization •Angler Utilization
Commercial fish and shellfish	•Commercially harvested areas and adjacent shellfish beds
Finfish spawning and rearing	•Habitat directly within proposed footprint
Larval Transport	•Up-bay migration of young of marine/high mesohaline species •Down- bay migration of early lifestages of anadromous species
SAV and Shallow Water habitat	•Presence of SAV •Depths less than 2 meters
Waterfowl use	•Areas known to be utilized for feeding/refuge
Tidal Wetlands	•Presence of tidal wetlands
Terrestrial habitat and wildlife	•Infringement on uplands •Effects to Heron rookery
Protected species (RTE)	•Presence of shortnose sturgeon •Proximity to bald eagle nesting area
Recreational value	•Recreational boating (other than fishing) •Other activities: swimming, birding
Historic resources	•Potential presence of archeological sites •Potential presence of sites of historical significance
Aesthetic and Noise	•Proximity to populations centers
Fossil shell mining	•Infringement on fossil shell resources
CERCLA and Unexploded Ordnance (UXO)	•Potential for presence of UXO •Proximity to APG controlled area (an NPL site)
Navigation	•Proximity to charted navigation channels •Increased currents in navigation channels •Potential for environmental disaster

Table 7-2 Comparison of mean trace metal concentrations[a] to sediment contaminant guidelines

Metals[b] (mg/Kg)	Location					Sediment Guidelines[c]		
	Site No. 1	Site No. 2	Site No. 3	Site No. 4A	Site No. 4B	NOEL		PEL
Arsenic	**35.64**	**11.01**	**11.01**	**9.37**	**33.27**	8	-	64
Cadmium	**1.59**	7.60	**3.71**	**5.86**	0.15	1	-	7.5
Chromium	**59.52**	29.32	**39.82**	24.56	**41.38**	33	-	240
Copper	**81.32**	**30.85**	**34.91**	22.37	**52.67**	28	-	240
Lead	**119.74**	**38.37**	**47.19**	**26.72**	**123.13**	28	-	160
Mercury	**0.85**	**0.36**	**0.37**	**0.27**	**0.67**	0.1	-	1.4
Nickel	633.73	53.95	48.72	39.66	539.77	NA	-	NA
Zinc	828.43	**216.27**	**247.60**	**155.11**	793.80	68	-	300

(a) Concentrations normalized as per Eskin et al. (1994).
(b) Chesapeake Bay Toxic of Concern, candidate Toxic of Concern, or known toxin to aquatic organisms according to Eskin et al. (1994)
(c) PEL and NOEL values for marine and estuarine sediments taken from McDonald (1993)

Note: NA = Not Applicable; no sediment guidelines available in McDonald (1993)
Shaded concentrations exceed PEL values.
Bolded concentrations lie between PEL and NOEL values.
When analytical data were below detection limits, one-half the detection limit was used to calculate the mean.

Table 7-3 Metric values for Screening-Level B-IBI of five proposed island placement sites in Upper Chesapeake Bay

Metric / Attribute	Site 1 Low Mesohaline Silty Clay Sand	Site 2 High Mesohaline Clayey Silt	Site 3 High Mesohaline Clayey Silt	Site 4A Low Mesohaline Clayey Silt	Site 4B Low Mesohaline Sandy Clay Silt
Shannon-Weiner Diversity Index	2.33	2.18	1.89	1.80	1.68
Abundance (#/m^2)	3372	7348	5116	4856	5080
Biomass (g/m^2)	47.7	39.7	51.2	57.8	43.5
Abundance of Pollution- Indicative Taxa (%)	3.6	6.7	17.4	0.6	1.1
Abundance of Pollution-Sensitive Taxa (%)	45.6	19.4	26.1	71.5	77.6
Abundance of Carnivores/Omnivores (%)	NA	13.2	10.2	NA	NA

NA= metric Not Applicable to low mesohaline habitat.

Table 7-4 Benthic community B-IBI[a] scores for five proposed island placement sites in the Upper Bay

Metric / Attribute	**Site 1** Low Mesohaline[b] Silty Clay Sand	**Site 2** High Mesohaline[c] Clayey Silt	**Site 3** High Mesohaline[c] Clayey Silt	**Site 4A** Low Mesohaline[b] Clayey Silt	**Site 4B** Low Mesohaline[b] Sandy Clay Silt
Shannon-Weiner Diversity Index	3	3	1	3	1
Abundance (#/m^2)	3	1	1	3	3
Biomass (g/m^2)	1	3	1	1	1
Abundance of Pollution—Indicative Taxa (%)	5	3	3	5	5
Abundance[d] of Pollution—Sensitive Taxa (%)	5	1	1	5	5
Abundance of Carnivores/Omnivores (%)	NA	3	3	NA	NA
AVERAGE SCORE[e]	3.4	2.3	1.7	3.4	3.0
Condition	Little apparent signs of stress	Exhibits signs of stress	Exhibits signs of stress	Little apparent signs of stress	Little apparent signs of stress

(a) From Ranasinghe et al. 1994, Ranasinghe et al. 1996, Weisberg et al. 1997.
(b) Score based upon criteria for low mesohaline habitats (Weisberg et al. 1997); abundance of carnivores/omnivores not applicable (NA) to this habitat.
(c) Score based upon criteria for high mesohaline mud habitats (Weisberg et al. 1997)
(d) Abundance substituted for biomass.
(e) Average score is the B-IBI.

Table 7-5 Upper Bay island placement sites: Environmental effects on existing conditions base evaluation matrix

PARAMETER	PROPOSED SITES					
	SITE NO. 1	SITE NO. 2	SITE NO. 3/3S [a]	SITE NO. 4A	SITE NO. 4B	SITE NO. 4B-R [b]
Water Quality	-1	+1	+1	-1	-1	-1
Salinity	0	0	0	0	0	0
Hydrodynamic effects	+1	+1	+1	-1	-1	-1
Sediment Quality	+1	+1	0	0	+1	+1
Benthic Community and Habitat	-1	+1	+1	-1	-1	-1
Recreational Fishery	-1	+1	0	-1	-1	+1
Commercial Fish and Shellfish	-1	-1	-1	-1	-1	-1
Finfish Spawning and Rearing	0	+1	+1	-1	-1	-1
Larval Transport	0	0	0	0	0	-1
SAV and Shallow Water Habitat	+1	+1	+1	+1	-1	+1
Waterfowl Use	+1	+1	+1	-1	-1	+1
Tidal Wetlands	+1	+1	+1	+1	-1	0
Terrestrial Habitat and Wildlife	+1	+1	+1	+1	-1	0
RTE Species (c)	-1	-1	-1	-1	-1	-1
Recreational Value	0	+1	0	-1	-1	-1
Historic Resources	+1	+1	+1	+1	-1	+1
Aesthetics and Noise	0	+1	+1	+1	+1	+1
Fossil Shell Mining	-1	+1	+1	-1	+1	+1
CERCLA & UXO potential	+1	+1	+1	-1	-1	-1
Navigation	+1	-1	+1	-1	-1	-1
TOTAL	**3**	**12**	**11**	**-7**	**-12**	**-2**

(a) Has a potentially significant beneficial use
(b) Small site only: 40 MCY (+/-) capacity
(c) One potential endangered species at all sites; two endangered species potentially present at Site 4B.
Key for Base Evaluation: +1 = resource already impacted or no impact expected; -1= Projected impact to resource; 0 = not enough conclusive evidence to make a definitive evaluation or evidence is ambiguous (shaded) or somewhat affected already/little further impact expected.
Construction at Sites 4A & 4B may borrow material from Site No. 1, which would impact the benthic community and fish habitat at that site.
Resource agents consider effects to larval transport and salinity to be the most importatant issues for island construction in the upper Bay.

Table 7-6 Upper Bay Island placement sites: Environmental effects on existing conditions ranking matrix—weighted evaluations

FACTOR	Weighting Factor	PROPOSED SITES					
		SITE NO. 1	SITE NO. 2	SITE NO. 3/3S [a]	SITE NO. 4A	SITE NO. 4B	SITE NO. 4B-R [b]
Water Quality (wq)	2	-2	2	2	-2	-2	-2
Salinity	4	0	0	0	0	0	0
Hydrodynamic effects (ero*4)	4	0	4	1	-4	-4	-4
Sediment Quality (sub)	2	2	2	0	4	2	2
Benthic Community and Habitat (sub + wq/2)	2	-2	2	2	-2	-2	-2
Recreational Fishery (fsh or slf)	4	0	4	0	-4	-4	4
Commercial Fish and Shellfish (slf)	4	0	-4	1	-4	-4	-4
Finfish Spawning and Rearing Habitat	4	0	4	4	-4	4	4
Larval Transport	6	0	-4	0	0	0	0
SAV and Shallow Water Habitat (sav)	4	4	4	4	4	4	4
Waterfowl Use (fwl)	4	0	1	1	-1	-1	4
Tidal Wetlands (tw)	4	0	3	1	4	-3	0
Terrestrial Habitat and Wildlife (for)	2	2	2	2	2	-2	0
RTE Species(rte)	5 (c)	-5	-5	-5	-5	-10	-5
Recreational Value (fsh/2)	2	0	2	0	-2	-2	-2
Historic Resources (arc + hst/2)	4	0	-4	0	4	4	0
Aesthetics and Noise (pop)	2	0	2	2	2	2	2
Fossil Shell Mining	2	-2	2	2	-2	2	2
CERCLA & UXO potential	5	5	5	5	-5	-5	-5
Navigation	4	4	-4	4	-4	-4	-4
TOTAL		**10**	**30**	**30**	**-24**	**-49**	**-13**
Sum of weights (d)	66	54	56	50	56	56	54
Weighted Average		0.18	0.54	0.60	-0.42	-0.88	-0.24

(a) Has a potentially significant beneficial use
(b) Small site only: 40 MCY (+/-) capacity
(c) 5 for each endangered species potentially present
(d) Sum of weighting factors including only parameters that don't have shaded zeros (lack of information).
Key for Weighted Evaluation: Weighting Factor x Base Evaluation = Weighted Evaluation. Weights (and variables) derived from the Port of Baltimore Dredged Material Management Draft Master Plan (1989). Weighted average = TOTAL score/sum of weights.
Key for Base Evaluation: +1 = resource already impacted or no impact expected; -1= Projected impact to resource; 0 = not enough conclusive evidence to make a definitive score or evidence is ambiguous (shaded) or somewhat affected already/little further impact expected.
Construction at Sites 4A & 4B may borrow material from Site No. 1, which would impact the benthic community and fish habitat at that site.
Resource agents consider effects to larval transport and salinity to be the most importatant issues for island construction in the upper Bay.

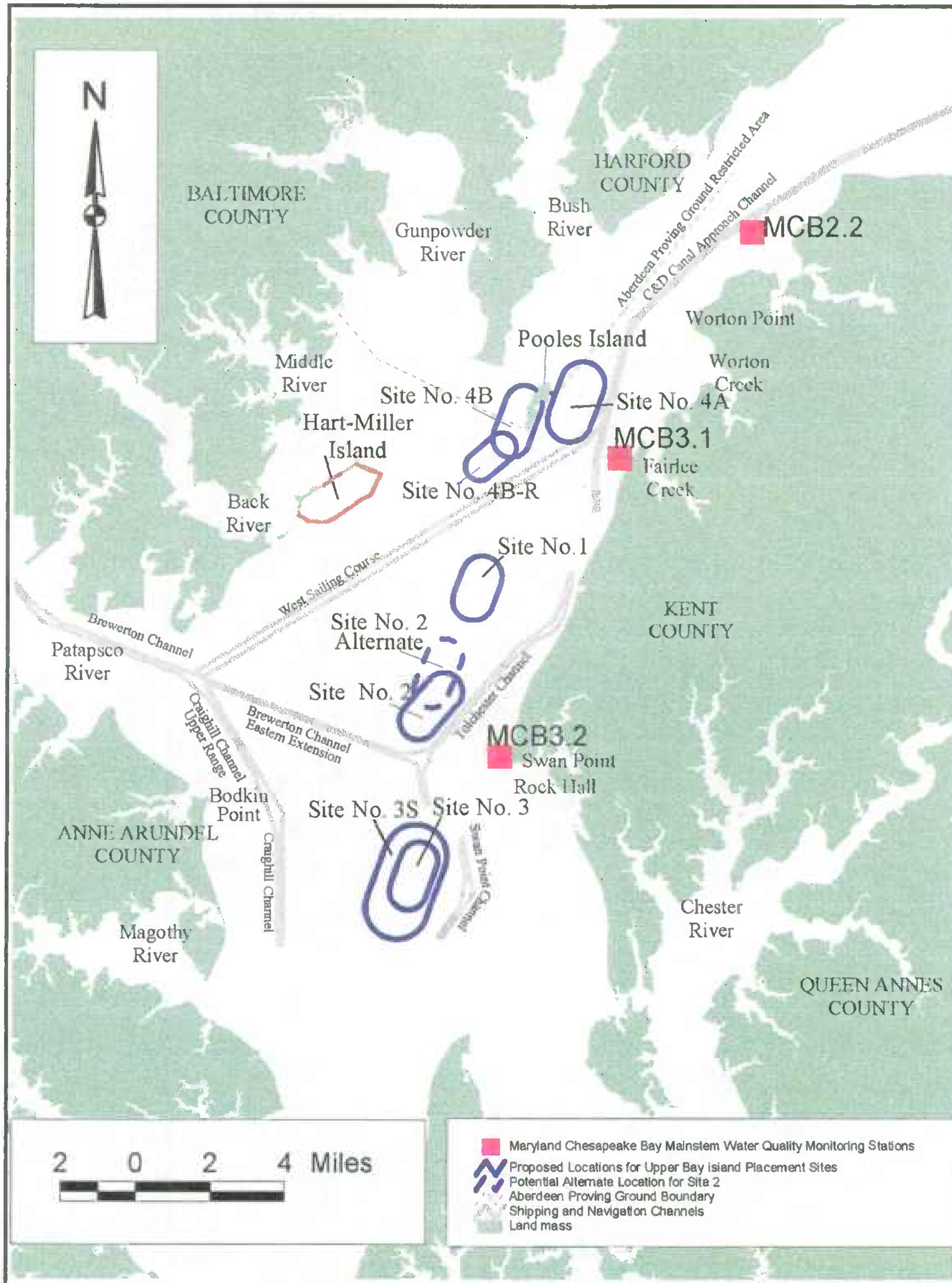

Figure 7-1. Chesapeake Bay Mainstem Water Quality Monitoring Stations in the vicinity of the five proposed island placement sites.

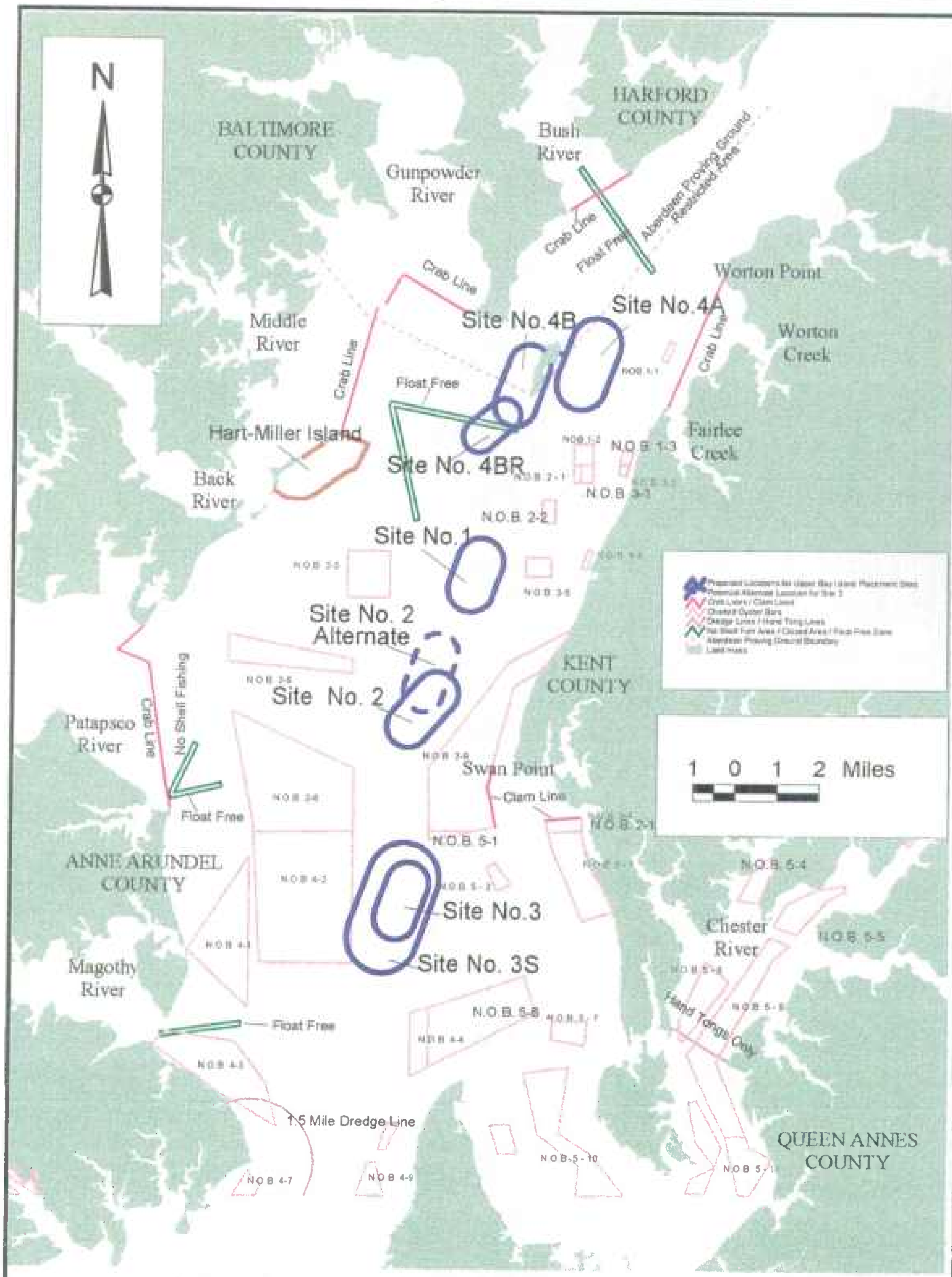

Figure 7-2. Locations of charted oyster bars and other shellfish harvest areas in the project area.

Source: Maryland Department of Natural Resources

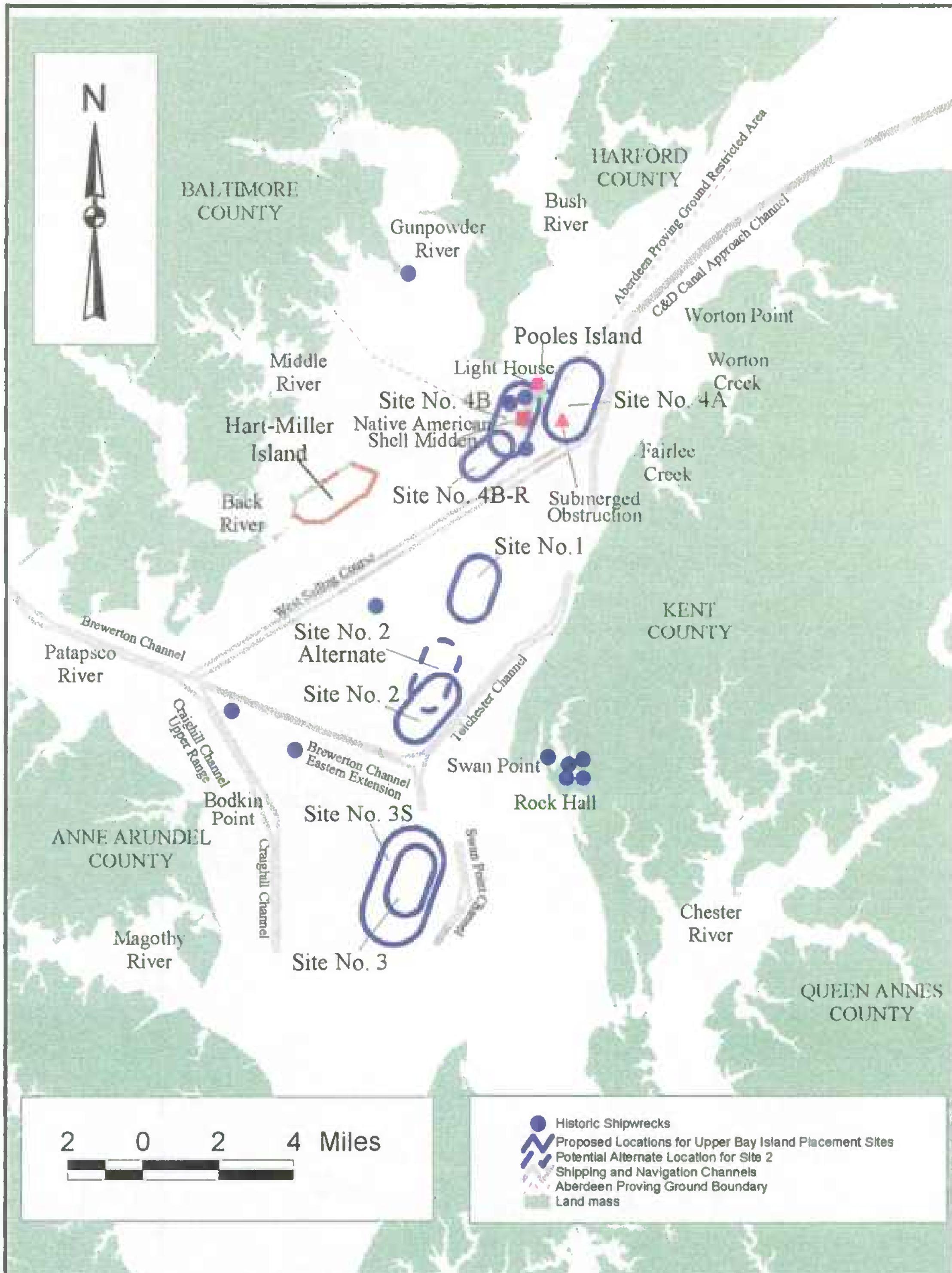

Figure 7-3. Locations of submerged obstructions and historical structures in the upper Chesapeake Bay study area.

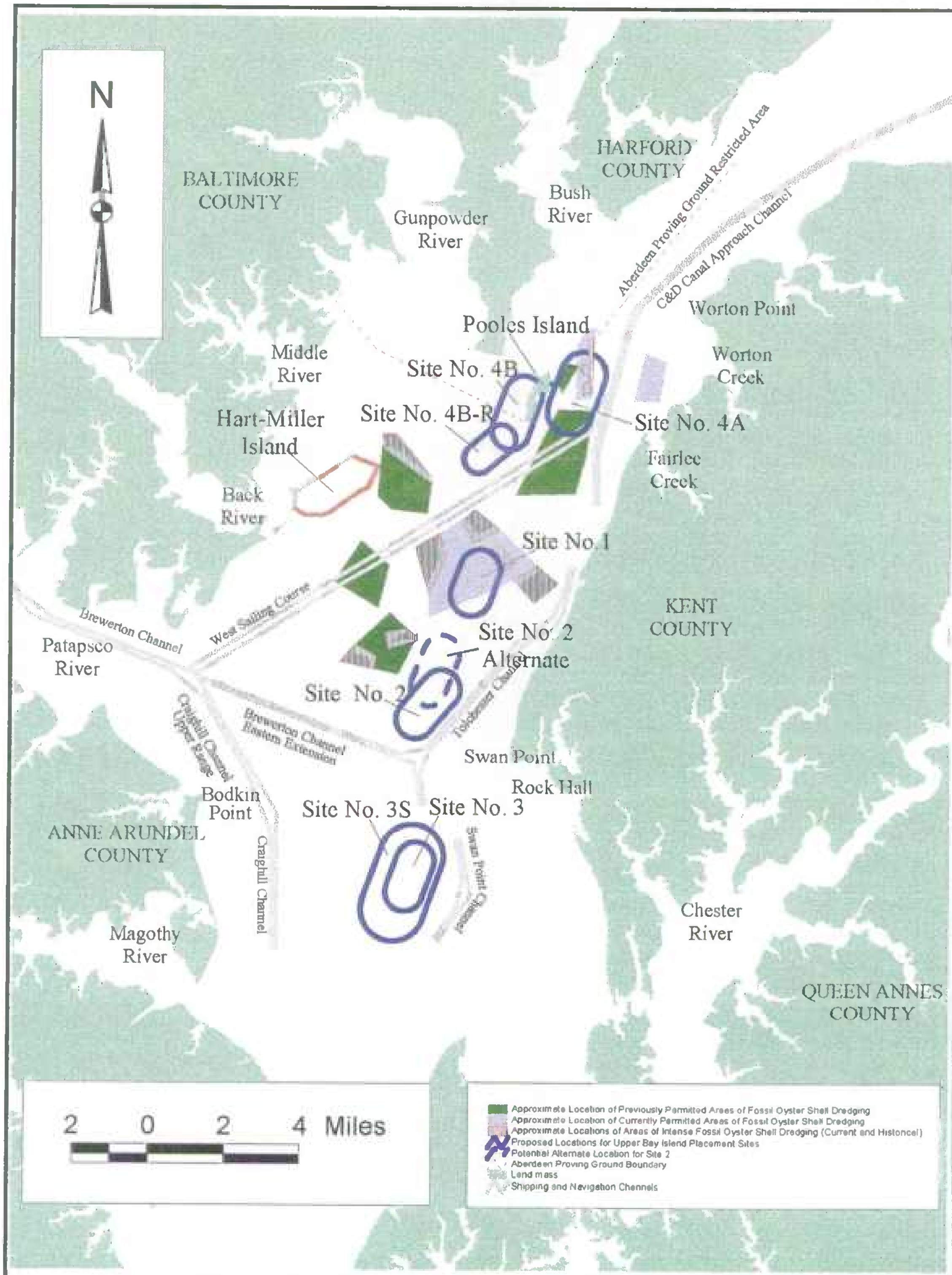

Figure 7-4. Existing fossil oyster shell dredging areas in the upper Chesapeake Bay.

8.0 SUMMARY AND CONCLUSIONS

8.1 Site 1

8.1.1 General Site Characteristics

- Site is located approximately 1.5 miles north of the Tolchester Channel. Site is also known as Tolchester Beach West.
- Water depth is approximately 10–16 ft. Average water depth is 12 ft.
- Site alignments studied are (1) surface area of 1,060 acres with a dike elevation of 25 ft, and (2) surface area of 790 acres and a dike elevation of 35 ft.

8.1.2 Cost Considerations

- Least expensive site by a small margin.
- Best site in terms of foundation material for site construction. Bottom is approximately 10–20 ft of sand underlaid by stiff clay.
- Best site as a source of borrow material. Sand for dike construction is likely to be available at the site.

8.1.3 Environmental Factors

- Benthic communities are relatively balanced based upon the Chesapeake Bay benthic index of biotic integrity.
- Site is located near an artificial reef that is a permitted fishing haven. Site lies within an area identified as important for recreational and commercial fishing and at the southern end of spawning and nursery sites for some species. Some fossil shell is present.
- Site has geological features that suggest it could have been the location of an ancient island.
- Preliminary results of hydrodynamic modeling suggest that a containment island at this site would have moderate effects (relative to the other sites studied) on current velocity, residence times, salinity, and dispersion of effluent from HMI.
- In the long term, the only potential beneficial use would be as a terrestrial island habitat, although some shallow water enhancements would be possible due to surrounding depths.

8.2 Site 2

8.2.1 General Site Characteristics

- Site is located less than 1 mile north of the intersection of Brewerton Channel and Tolchester Channel. Site is also known as Site 168 or Tolchester Beach Southwest.

- Water depth is approximately 16–28 ft. Average water depth is 23 ft.

- Site alignments studied are (1) surface area of 1,195 acres with a dike elevation of 15 ft, and (2) surface area of 1,075 acres and a dike elevation of 18 ft.

8.2.2 Cost Considerations

- Site has weak foundation soils and, as a result, high site development costs. One-third of the site overlaps an area formerly used for the placement of dredged material.

- Bottom consists of approximately 35–55 ft of soft to very soft clay. Extensive undercutting or displacement of the clay would be required.

- Sand for dike construction is not available at the site and would need to be imported from either the area around Site 1 or from the Craighill Channel. Note: The subaqueous mining of the Craighill Channel could reduce the cost of the dredging program; the voided pockets of sand could be cheaply backfilled with material dredged from other portions of the channel.

- The site might be shifted to the northwest, further from the navigation channel and potentially to a firmer, sandy bottom. The available data are insufficient to evaluate this option further.

8.2.3 Environmental Factors

- Site with the least environmental trade-offs; existing benthic communities are stressed.

- Site has lower recreational and comercial fisheries value than do several other sites and is not a significant nursery area.

- Preliminary results of hydrodynamic modeling suggest that a containment island at this site would have the fewest effects overall on residence times, salinity, and dispersion of effluent from HMI. Navigation could be affected by the site's proximity to the channel and localized increases in current velocity.

- In the long term, the site has a potential beneficial use only as a terrestrial island habitat.

8.3 Site 3

8.3.1 General Site Characteristics

- Site is located 1 mile west of the Swan Point Channel and 8 miles north of the Bay Bridge. Site is also known as Site 171 or Bay Bridge North.

- Deepest site. Water depth is approximately 24–32 ft. Average water depth is 28 ft.

- Site alignments studied are (1) surface area of 1,065 acres with dike elevation of 15 ft, and (2) surface area of 975 acres and a dike elevation of 18 ft.

8.3.2 Cost Considerations

- Most expensive site.

- Site has weak foundation soils and, as a result, high site development costs.

- Bottom consists of over 40 ft of soft to very soft clay. Extensive undercutting or displacement of the clay would be required.

- Sand for dike construction is not available at the site and would need to be imported, most likely from the Craighill Channel. Note: The subaqueous mining of the Craighill Channel could reduce the cost of the overall dredging program; the voided pockets of sand could be backfilled inexpensively with material dredged from other portions of the channel.

8.3.3 Environmental Factors

- Among the sites with the least environmental trade-offs; existing benthic communities are stressed.

- Site supports commercial harvests, predominantly in winter. Hodges and Swan Point bars, which are nearby, are among the most significant oyster harvest areas in the upper Bay.

- Preliminary results of hydrodynamic modeling suggest that a containment island at this site would have greater effects (relative to the other sites studied) on residence times and dispersion of effluent from HMI. Changes in current velocity would be low to moderate, and changes in salinity patterns would be low compared to the other sites.

- In the long term, the site has a potential beneficial use only as a terrestrial island habitat.

8.4 Subsite 3-S

8.4.1 General Site Characteristics

- Site is a submerged area west of the Swan Point Channel.
- Water depth is approximately 16–40 ft. Average water depth is 29.5 ft.
- Site alignment studied has a surface area of 3,000 acres with a dike elevation of -10 ft.
- Site would consume very large surface area unless reduced in size and combined with a second site.

8.4.2 Cost Considerations

- Second least-expensive site by a small margin.
- Site has low dredging and transport costs due to its location near the centroid of the channels and the potential for direct placement of dredged material from scows or hoppers.
- Site might need to be capped and maintained after filling (costs included in analysis).
- Sand for dike construction is not available at the site and would need to be imported, most likely from the Craighill Channel. Note: The subaqueous mining of the Craighill Channel could reduce the cost of the overall dredging program; the voided pockets of sand could be backfilled inexpensively with material dredged from other portions of the channel.

8.4.3 Environmental Factors

- Among the sites with the fewest environmental trade-offs; existing benthic communities are stressed.
- Site supports some commercial harvests, predominantly in winter.
- Preliminary results of hydrodynamic modeling suggest that a containment island at this site would have moderate effects overall on current velocity, salinity, and dispersion of effluent from HMI. The effect on residence times would be greater at this site than at most other sites.
- Once filled, the submerged containment island could be developed into a shallow-water reef (fish habitat) or oyster bar, a potentially significant beneficial use.

8.5 Site 4A

8.5.1 General Site Characteristics

- Site is located 0.5 miles east of Pooles Island, with a small portion lying within APG boundaries. Site is also known as Pooles Island East.
- Water depth is approximately 10–34 ft. Average water depth is 15 ft.
- Site alignments studied are (1) surface area of 1,475 acres with a dike elevation of 15 ft, and (2) surface area of 1,300 acres and a dike elevation of 18 ft.

8.5.2 Cost Considerations

- Site has weak foundation soils and, as a result, high site development costs. Foundation soils were assumed to be similar to those of Site 2 based on acoustic surveys and general observations on site topography and test boring data.
- Bottom consists of over 40 ft of soft to very soft clay. Extensive undercutting or displacement of the clay would be required.
- Sand for dike construction is not available at the site and would need to be imported.
- UXO could be present along the western areas, requiring careful construction procedures and potentially costly removal.

8.5.3 Environmental Factors

- Relatively balanced based on the Chesapeake Bay benthic index of biotic integrity.
- Site potentially supports various life stages of commercially important species. Significant crab fishery located nearby. Site is near spawning habitats and is a nursery for many species. Site is probably used as feeding and staging area for waterfowl.
- Preliminary results of hydrodynamic modeling suggest that a containment island at this site would have the greatest effects overall on current velocity and salinity. The effect on dispersion of effluent from HMI would also be greater at this site than most other sites, whereas residence times would be affected to a lesser degree.
- In the long term, the site has a potential beneficial use only as a terrestrial island habitat.

8.6 Site 4B

8.6.1 General Site Characteristics

- Site is located south and west of Pooles Island, with portions lying within APG boundaries.
- Water depth is approximately 4–16 ft. Average water depth is 9 ft.
- Site alignments studied are (1) surface area of 1,125 acres with a dike elevation of 25 ft, and (2) surface area of 825 acres and a dike elevation of 35 ft.

8.6.2 Cost Considerations

- Subsurface conditions are highly variable, ranging from dense sand covered by soft clay at the north end to more than 30 ft of soft to very soft clay at the south end. The weak soils could be completely undercut and replaced with fill.
- Sand is available for dike construction, but UXO could complicate sand removal.
- UXO should be anticipated throughout the site and especially along the northern areas, requiring careful construction procedures and potentially costly removal.

8.6.3 Environmental Factors

- Relatively balanced based on the Chesapeake Bay benthic index of biotic integrity.
- Site potentially supports various life stages of commercially important fish species. Site is a spawning area for at least one species and an important nursery for commercial species.
- Site is used intensively by waterfowl and other birds. A large heron rookery is located on the south end of Pooles Island. A bald eagle's nest is located on Pooles Island.
- Pooles Island has historical and archeological resources such as the oldest lighthouse in the state and a native American shell midden.
- Preliminary results of hydrodynamic modeling suggest that a containment island at this site would have moderate effects overall on residence times, salinity, and dispersion of effluent from HMI. Changes in current velocity would be low to moderate compared to other sites.
- In the long term, site has potential beneficial use in the creation of intertidal marshes and upland habitats, which are preferred by some resource agencies.

8.7 Subsite 4B-R

8.7.1 General Site Characteristics

- Site 4B-R overlaps the southern tip of Site 4B and is not connected to Pooles Island.
- Water depth is approximately 12–14 ft. Average water depth is 13 ft.
- Site alignments studied are (1) surface area of 780 acres with a dike elevation of 15 ft, and (2) surface area of 680 acres with a dike elevation of 18 ft.
- Site has only half the required capacity and therefore would need to combined with a second small site (e.g., part of Site 3-S).

8.7.2 Cost Considerations

- Site has weak foundation soils and, as a result, high site development costs.
- Sediment is assumed to consist of soft to very soft, silty clays with an average layer thickness of 10 ft. Extensive undercutting or displacement of the clay would be required.
- Sand for dike construction is not available at the site and would need to be imported.
- UXO are likely to be present, requiring careful construction procedures and possibly expensive removal.

8.7.3 Environmental Factors

- Site lacks the terrestrial, natural, historical, and archeological resources associated with Pooles Island and therefore would involve fewer environmental trade-offs than Site 4B.
- Preliminary results of hydrodynamic modeling suggest that a containment island at this site would have moderate effects (relative to the other sites studied) on salinity, residence times, and dispersion of effluent from HMI. Changes in current velocity would be low to moderate compared to other sites.
- In the long term, the site has a potential beneficial use only as a terrestrial island habitat.

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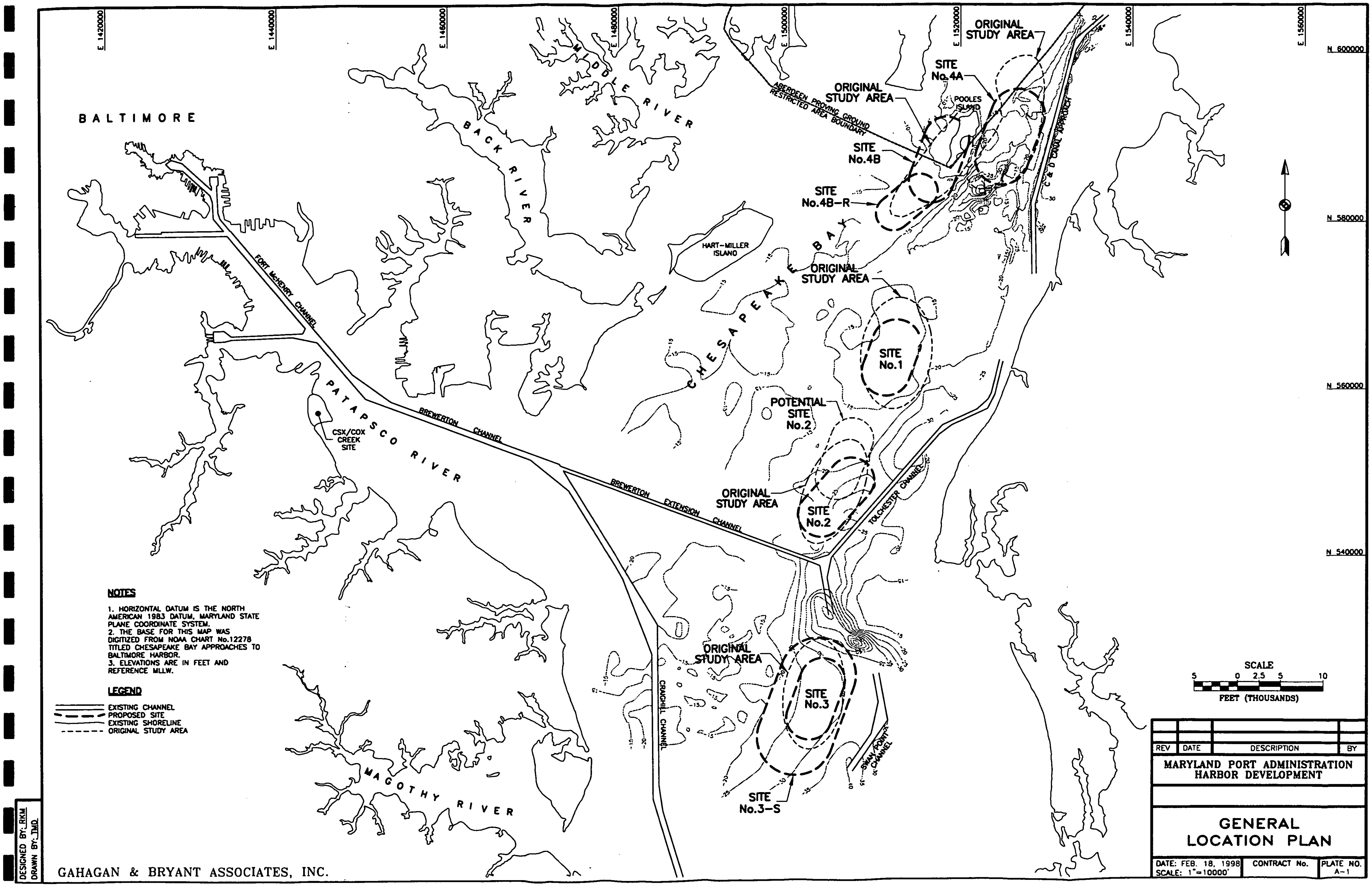
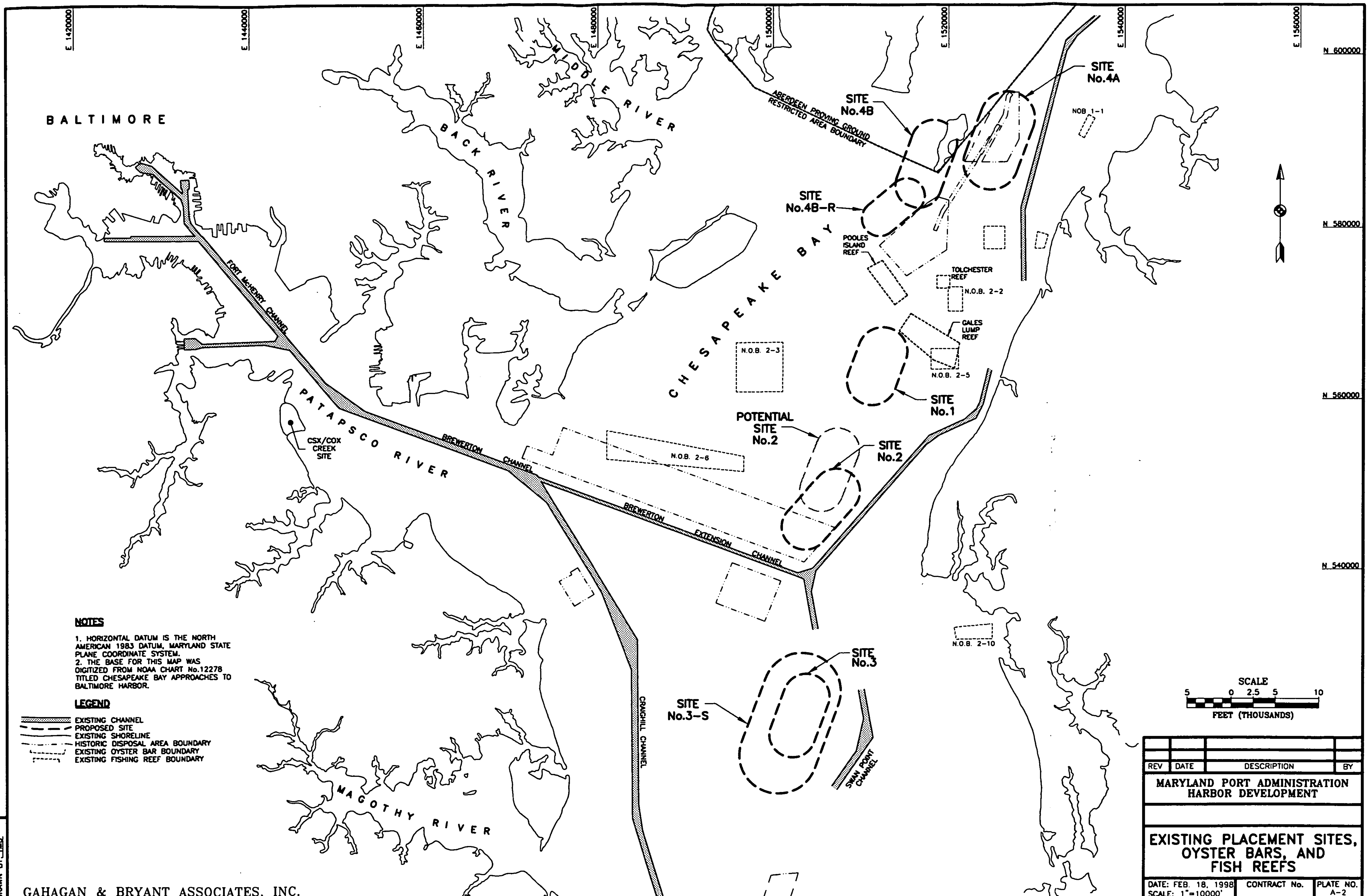
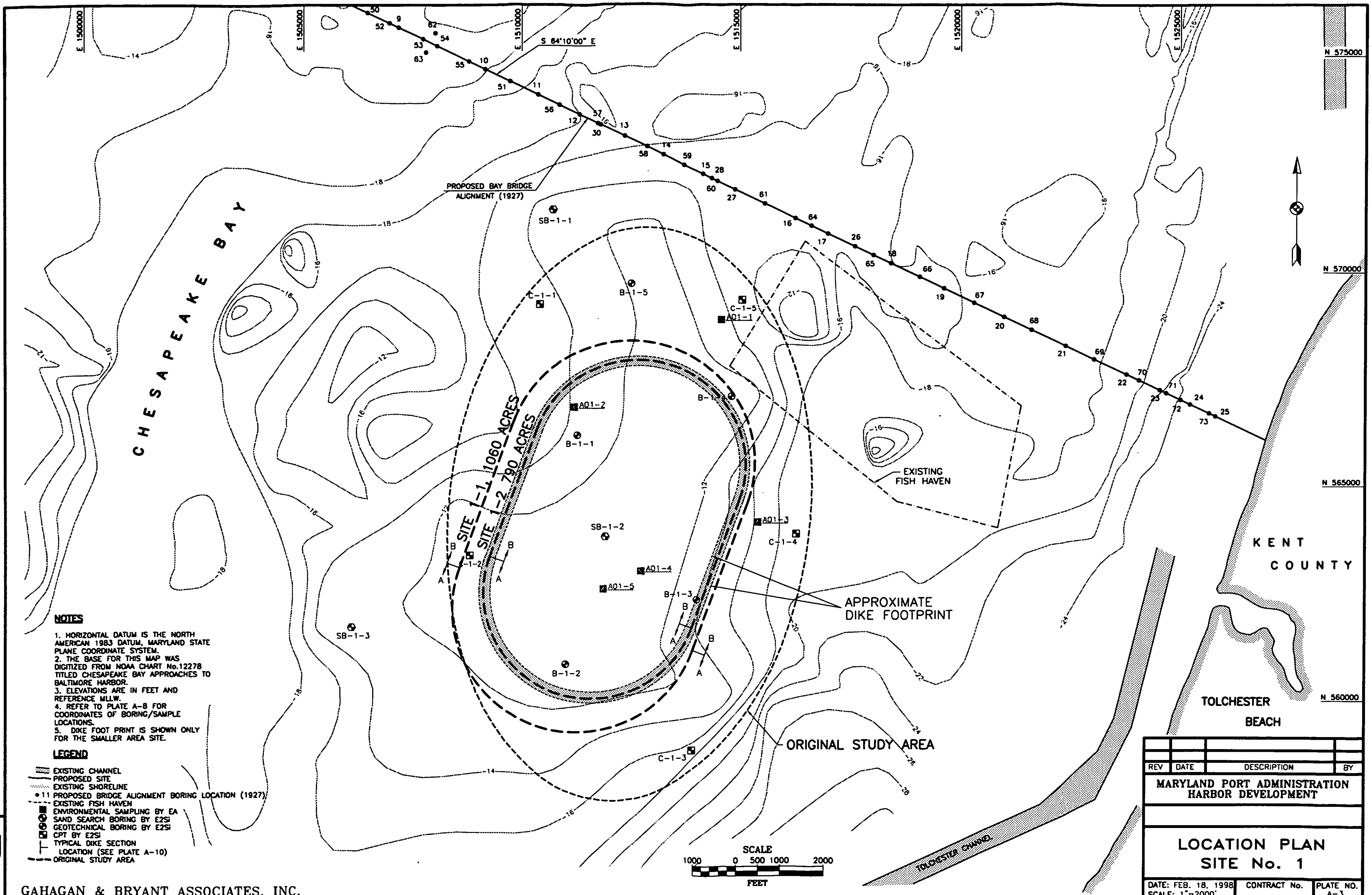
APPENDIX A
BASE MAPS AND DIKE CROSS-SECTIONS

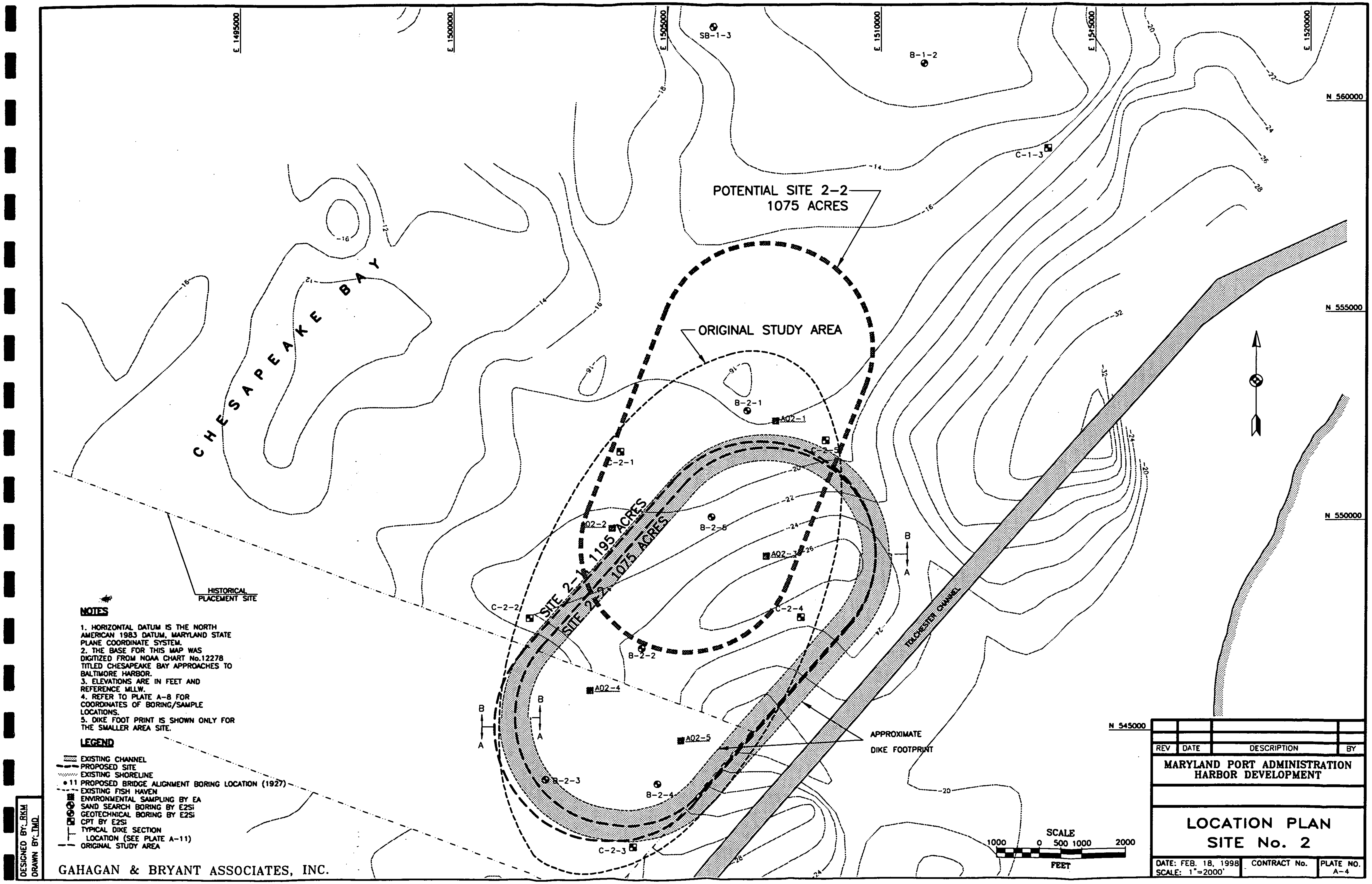


E 1420000
E 1440000
E 1460000
E 1480000
E 1500000
E 1520000
E 1540000
E 1560000
N 600000
N 580000
N 560000
N 540000
BALTIMORE
MIDDLE RIVER
BACK RIVER
PATAPSCO RIVER
MAGOTHY RIVER
CHESAPEAKE BAY
HART-MILLER ISLAND
POOLES ISLAND
CSX/COX CREEK SITE
FORT McHENRY CHANNEL
BREWERTON CHANNEL
BREWERTON EXTENSION CHANNEL
CRAGHILL CHANNEL
TOLCHESTER CHANNEL
SWAN POINT CHANNEL
C & D CANAL APPROACH
ABERDEEN PROVING GROUND RESTRICTED AREA BOUNDARY
ORIGINAL STUDY AREA
SITE No.4A
SITE No.4B
SITE No.4B-R
SITE No.1
POTENTIAL SITE No.2
SITE No.2
SITE No.3
SITE No.3-S
NOTES
1. HORIZONTAL DATUM IS THE NORTH AMERICAN 1983 DATUM, MARYLAND STATE PLANE COORDINATE SYSTEM.
2. THE BASE FOR THIS MAP WAS DIGITIZED FROM NOAA CHART No.12278 TITLED CHESAPEAKE BAY APPROACHES TO BALTIMORE HARBOR.
3. ELEVATIONS ARE IN FEET AND REFERENCE MLLW.
LEGEND
EXISTING CHANNEL
PROPOSED SITE
EXISTING SHORELINE
ORIGINAL STUDY AREA
SCALE
5 0 2.5 5 10
FEET (THOUSANDS)
REV DATE DESCRIPTION BY
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT
GENERAL LOCATION PLAN
DATE: FEB. 18, 1998
SCALE: 1"=10000'
CONTRACT No.
PLATE NO. A-1
DESIGNED BY: RKM
DRAWN BY: TMD
GAHAGAN & BRYANT ASSOCIATES, INC.

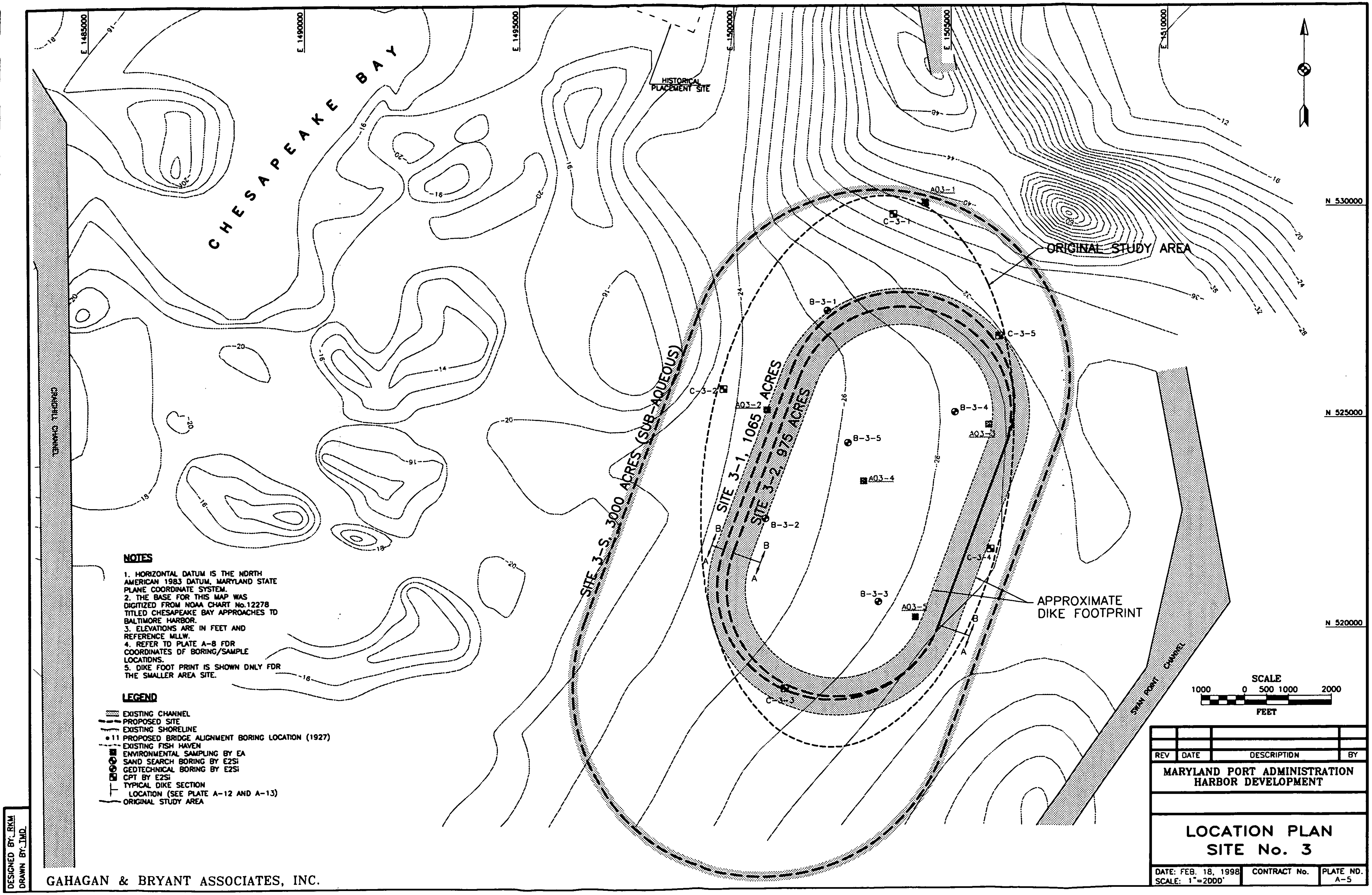

E 1420000
E 1440000
E 1460000
E 1480000
E 1500000
E 1520000
E 1540000
E 1560000
N 600000
N 580000
N 560000
N 540000
BALTIMORE
MIDDLE RIVER
BACK RIVER
CHESAPEAKE BAY
PATAPSCO RIVER
MAGOTHY RIVER
FORT McHENRY CHANNEL
BREWERTON CHANNEL
BREWERTON EXTENSION CHANNEL
CRAIGHILL CHANNEL
SWAN POINT CHANNEL
ABERDEEN PROVING GROUND RESTRICTED AREA BOUNDARY
SITE No.4A
SITE No.4B
SITE No.4B-R
POOLES ISLAND REEF
TOLCHESTER REEF
GALES LUMP REEF
NOB 1-1
N.O.B. 2-2
N.O.B. 2-3
N.O.B. 2-5
N.O.B. 2-6
N.O.B. 2-10
SITE No.1
POTENTIAL SITE No.2
SITE No.2
SITE No.3
SITE No.3-S
CSX/COX CREEK SITE
NOTES
1. HORIZONTAL DATUM IS THE NORTH AMERICAN 1983 DATUM, MARYLAND STATE PLANE COORDINATE SYSTEM.
2. THE BASE FOR THIS MAP WAS DIGITIZED FROM NOAA CHART No.12278 TITLED CHESAPEAKE BAY APPROACHES TO BALTIMORE HARBOR.
LEGEND
EXISTING CHANNEL
PROPOSED SITE
EXISTING SHORELINE
HISTORIC DISPOSAL AREA BOUNDARY
EXISTING OYSTER BAR BOUNDARY
EXISTING FISHING REEF BOUNDARY
SCALE
5 0 2.5 5 10
FEET (THOUSANDS)
REV DATE DESCRIPTION BY
MARYLAND PORT ADMINISTRATION HARBOR DEVELOPMENT
EXISTING PLACEMENT SITES, OYSTER BARS, AND FISH REEFS
DATE: FEB. 18, 1998
SCALE: 1"=10000'
CONTRACT No.
PLATE NO. A-2
DESIGNED BY: RKM
DRAWN BY: TMD
GAHAGAN & BRYANT ASSOCIATES, INC.



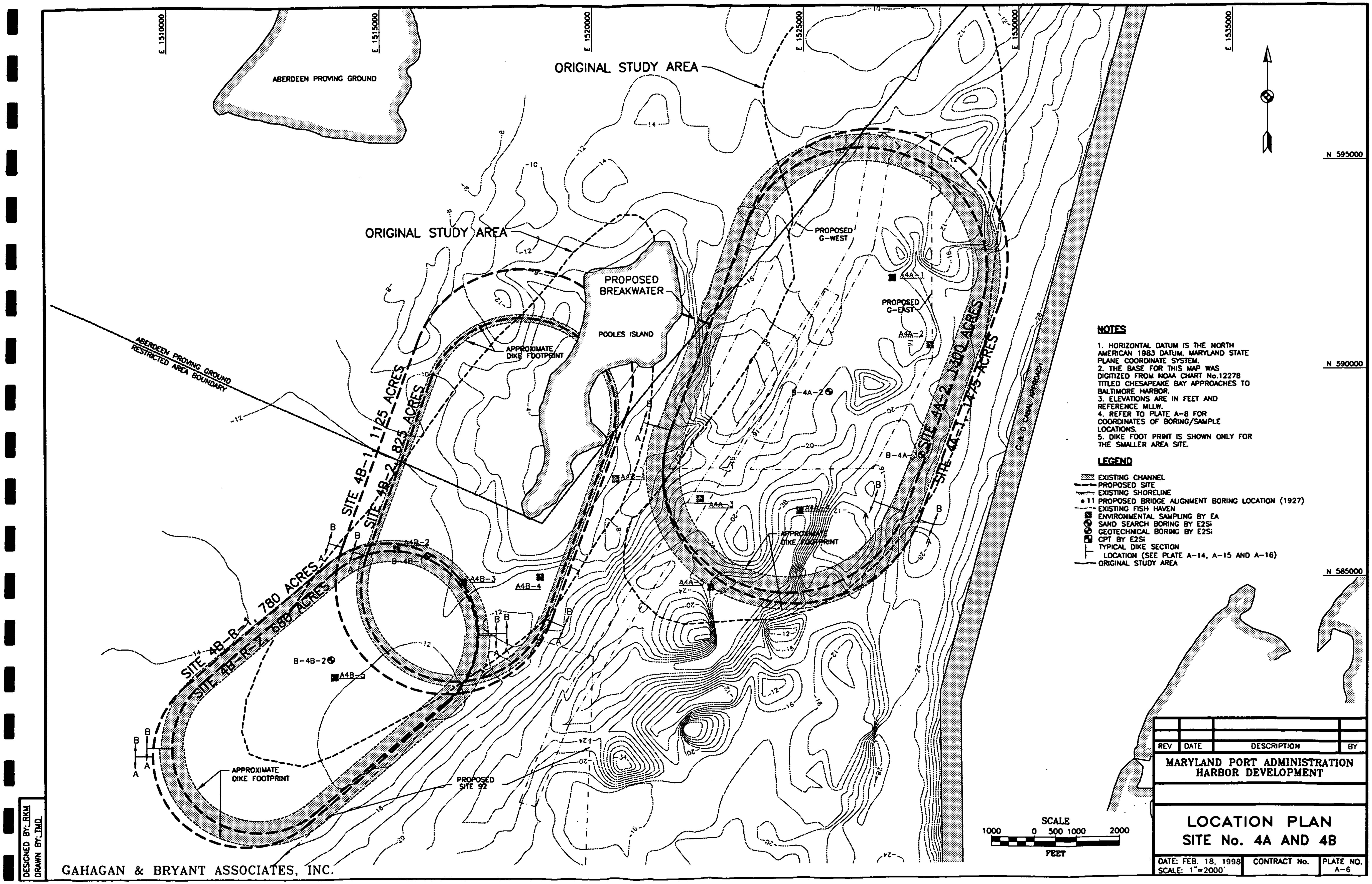
CHESAPEAKE BAY
KENT COUNTY
TOLCHESTER BEACH
TOLCHESTER CHANNEL
S 64°10'00" E
PROPOSED BAY BRIDGE ALIGNMENT (1927)
SITE 1-1, 1060 ACRES
SITE 1-2, 790 ACRES
APPROXIMATE DIKE FOOTPRINT
ORIGINAL STUDY AREA
EXISTING FISH HAVEN
SB-1-1
SB-1-2
SB-1-3
B-1-1
B-1-2
B-1-3
B-1-5
C-1-1
C-1-2
C-1-3
C-1-4
C-1-5
A01-1
A01-2
A01-3
A01-4
A01-5
E 1500000
E 1505000
E 1510000
E 1515000
E 1520000
E 1525000
N 575000
N 570000
N 565000
N 560000
NOTES
1. HORIZONTAL DATUM IS THE NORTH AMERICAN 1983 DATUM, MARYLAND STATE PLANE COORDINATE SYSTEM.
2. THE BASE FOR THIS MAP WAS DIGITIZED FROM NOAA CHART No.12278 TITLED CHESAPEAKE BAY APPROACHES TO BALTIMORE HARBOR.
3. ELEVATIONS ARE IN FEET AND REFERENCE MLLW.
4. REFER TO PLATE A-8 FOR COORDINATES OF BORING/SAMPLE LOCATIONS.
5. DIKE FOOT PRINT IS SHOWN ONLY FOR THE SMALLER AREA SITE.
LEGEND
EXISTING CHANNEL
PROPOSED SITE
EXISTING SHORELINE
• 11 PROPOSED BRIDGE ALIGNMENT BORING LOCATION (1927)
EXISTING FISH HAVEN
ENVIRONMENTAL SAMPLING BY EA
SAND SEARCH BORING BY E2Si
GEOTECHNICAL BORING BY E2Si
CPT BY E2Si
TYPICAL DIKE SECTION LOCATION (SEE PLATE A-10)
ORIGINAL STUDY AREA
SCALE
1000 0 500 1000 2000
FEET
REV
DATE
DESCRIPTION
BY
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT
LOCATION PLAN
SITE No. 1
DATE: FEB. 18, 1998
SCALE: 1"=2000'
CONTRACT No.
PLATE NO.
A-3
DESIGNED BY: RKM
DRAWN BY: TMD
GAHAGAN & BRYANT ASSOCIATES, INC.



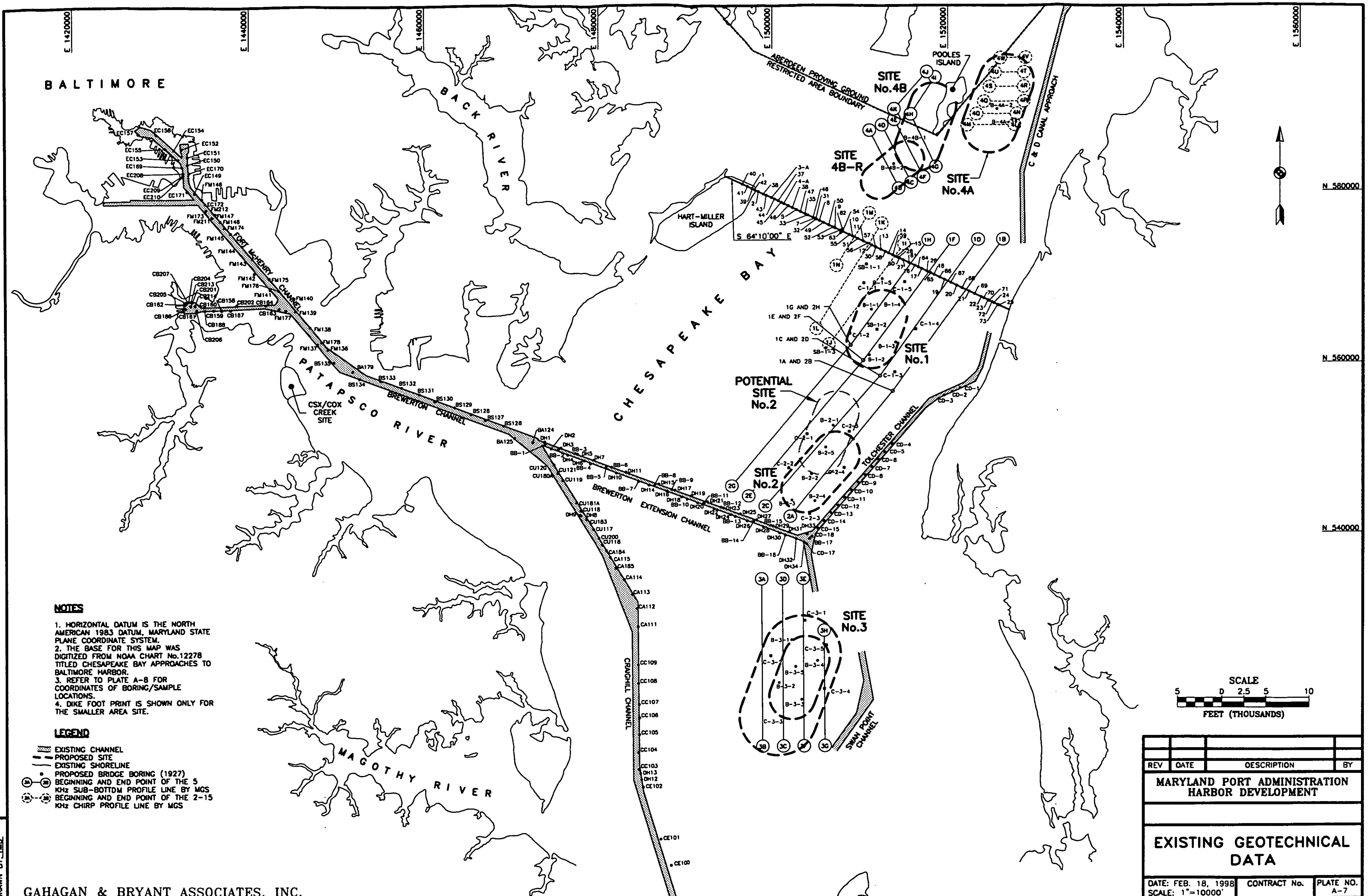
E 1495000
E 1500000
E 1505000
E 1510000
E 1515000
E 1520000
N 560000
N 555000
N 550000
N 545000
CHESAPEAKE BAY
POTENTIAL SITE 2-2
1075 ACRES
ORIGINAL STUDY AREA
SITE 2-1, 1195 ACRES
SITE 2-2, 1075 ACRES
HISTORICAL PLACEMENT SITE
TOLCHESTER CHANNEL
APPROXIMATE DIKE FOOTPRINT
SB-1-3
B-1-2
C-1-3
B-2-1
A02-1
C-2-5
C-2-1
B-2-5
A02-2
A02-3
C-2-4
C-2-2
B-2-2
A02-4
A02-5
B-2-3
B-2-4
C-2-3
NOTES
1. HORIZONTAL DATUM IS THE NORTH AMERICAN 1983 DATUM, MARYLAND STATE PLANE COORDINATE SYSTEM.
2. THE BASE FOR THIS MAP WAS DIGITIZED FROM NOAA CHART No.12278 TITLED CHESAPEAKE BAY APPROACHES TO BALTIMORE HARBOR.
3. ELEVATIONS ARE IN FEET AND REFERENCE MLLW.
4. REFER TO PLATE A-8 FOR COORDINATES OF BORING/SAMPLE LOCATIONS.
5. DIKE FOOT PRINT IS SHOWN ONLY FOR THE SMALLER AREA SITE.
LEGEND
EXISTING CHANNEL
PROPOSED SITE
EXISTING SHORELINE
11 PROPOSED BRIDGE ALIGNMENT BORING LOCATION (1927)
EXISTING FISH HAVEN
ENVIRONMENTAL SAMPLING BY EA
SAND SEARCH BORING BY E2Si
GEOTECHNICAL BORING BY E2Si
CPT BY E2Si
TYPICAL DIKE SECTION LOCATION (SEE PLATE A-11)
ORIGINAL STUDY AREA
SCALE
1000 0 500 1000 2000
FEET
REV
DATE
DESCRIPTION
BY
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT
LOCATION PLAN
SITE No. 2
DATE: FEB. 18, 1998
SCALE: 1"=2000'
CONTRACT No.
PLATE NO.
A-4
DESIGNED BY: RKM
DRAWN BY: TMD
GAHAGAN & BRYANT ASSOCIATES, INC.



CHESAPEAKE BAY
E 1485000
E 1490000
E 1495000
E 1500000
E 1505000
E 1510000
N 530000
N 525000
N 520000
HISTORICAL PLACEMENT SITE
CRAIGHILL CHANNEL
SWAN POINT CHANNEL
ORIGINAL STUDY AREA
APPROXIMATE DIKE FOOTPRINT
SITE 3-S, 3000 ACRES (SUB-AQUEOUS)
SITE 3-1, 1065 ACRES
SITE 3-2, 975 ACRES
A03-1
A03-2
A03-3
A03-4
A03-5
C-3-1
C-3-2
C-3-3
C-3-4
C-3-5
B-3-1
B-3-2
B-3-3
B-3-4
B-3-5
SCALE
1000 0 500 1000 2000
FEET
NOTES
1. HORIZONTAL DATUM IS THE NDRTH AMERICAN 1983 DATUM, MARYLAND STATE PLANE COORDINATE SYSTEM.
2. THE BASE FOR THIS MAP WAS DIGITIZED FROM NOAA CHART No.12278 TITLED CHESAPEAKE BAY APPROACHES TD BALTIMORE HARBOR.
3. ELEVATIONS ARE IN FEET AND REFERENCE MLLW.
4. REFER TD PLATE A-8 FDR COORDINATES DF BORING/SAMPLE LOCATIDNS.
5. DIKE FOOT PRINT IS SHOWN DNLY FDR THE SMALLER AREA SITE.
LEGEND
EXISTING CHANNEL
PROPOSED SITE
EXISTING SHORELINE
• 11 PROPOSED BRIDGE ALIGNMENT BORING LOCATION (1927)
EXISTING FISH HAVEN
ENVIRONMENTAL SAMPLING BY EA
SAND SEARCH BORING BY E2Si
GEDTECHNICAL BORING BY E2Si
CPT BY E2Si
TYPICAL DIKE SECTION LOCATION (SEE PLATE A-12 AND A-13)
ORIGINAL STUDY AREA
REV DATE DESCRIPTION BY
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT
LOCATION PLAN
SITE No. 3
DATE: FEB. 18, 1998
SCALE: 1"=2000'
CONTRACT No.
PLATE NO. A-5
DESIGNED BY: RKM
DRAWN BY: TMD
GAHAGAN & BRYANT ASSOCIATES, INC.



E 1510000
E 1515000
E 1520000
E 1525000
E 1530000
E 1535000
N 595000
N 590000
N 585000
ABERDEEN PROVING GROUND
ORIGINAL STUDY AREA
ORIGINAL STUDY AREA
PROPOSED BREAKWATER
POOLES ISLAND
ABERDEEN PROVING GROUND RESTRICTED AREA BOUNDARY
APPROXIMATE DIKE FOOTPRINT
PROPOSED G-WEST
PROPOSED G-EAST
SITE 4B-1, 1125 ACRES
SITE 4B-2, 825 ACRES
SITE 4B-R-1, 780 ACRES
SITE 4B-R-2, 680 ACRES
SITE 4A-2, 1300 ACRES
SITE 4A-1, 1475 ACRES
C & D CANAL APPROACH
APPROXIMATE DIKE FOOTPRINT
APPROXIMATE DIKE FOOTPRINT
PROPOSED SITE 92
A4A-1
A4A-2
A4A-3
A4A-4
A4A-5
A4B-1
A4B-2
A4B-3
A4B-4
A4B-5
B-4A-2
B-4A-1
B-4B-1
B-4B-2
NOTES
1. HORIZONTAL DATUM IS THE NORTH AMERICAN 1983 DATUM, MARYLAND STATE PLANE COORDINATE SYSTEM.
2. THE BASE FOR THIS MAP WAS DIGITIZED FROM NOAA CHART No.12278 TITLED CHESAPEAKE BAY APPROACHES TO BALTIMORE HARBOR.
3. ELEVATIONS ARE IN FEET AND REFERENCE MLLW.
4. REFER TO PLATE A-8 FOR COORDINATES OF BORING/SAMPLE LOCATIONS.
5. DIKE FOOT PRINT IS SHOWN ONLY FOR THE SMALLER AREA SITE.
LEGEND
EXISTING CHANNEL
PROPOSED SITE
EXISTING SHORELINE
• 11 PROPOSED BRIDGE ALIGNMENT BORING LOCATION (1927)
EXISTING FISH HAVEN
ENVIRONMENTAL SAMPLING BY EA
SAND SEARCH BORING BY E2Si
GEOTECHNICAL BORING BY E2Si
CPT BY E2Si
TYPICAL DIKE SECTION LOCATION (SEE PLATE A-14, A-15 AND A-16)
ORIGINAL STUDY AREA
SCALE
1000 0 500 1000 2000
FEET
REV | DATE | DESCRIPTION | BY
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT
LOCATION PLAN
SITE No. 4A AND 4B
DATE: FEB. 18, 1998
SCALE: 1"=2000'
CONTRACT No.
PLATE NO. A-6
DESIGNED BY: RKM
DRAWN BY: TMD
GAHAGAN & BRYANT ASSOCIATES, INC.



NOTES

1. HORIZONTAL DATUM IS THE NORTH AMERICAN 1983 DATUM, MARYLAND STATE PLANE COORDINATE SYSTEM.
2. THE BASE FOR THIS MAP WAS DIGITIZED FROM NOAA CHART No.12278 TITLED CHESAPEAKE BAY APPROACHES TO BALTIMORE HARBOR.
3. REFER TO PLATE A-8 FOR COORDINATES OF BORING/SAMPLE LOCATIONS.
4. DIKE FOOT PRINT IS SHOWN ONLY FOR THE SMALLER AREA SITE.

LEGEND

- EXISTING CHANNEL
- PROPOSED SITE
- EXISTING SHORELINE
- PROPOSED BRIDGE BORING (1927)
- (3A)—(3B) BEGINNING AND END POINT OF THE 5 KHz SUB-BOTTOM PROFILE LINE BY MGS
- (3A)- -(3B) BEGINNING AND END POINT OF THE 2-15 KHz CHIRP PROFILE LINE BY MGS

DESIGNED BY: RKM
DRAWN BY: TMD

GAHAGAN & BRYANT ASSOCIATES, INC.

REV	DATE	DESCRIPTION	BY

MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

EXISTING GEOTECHNICAL DATA

DATE: FEB. 18, 1998
SCALE: 1"=10000'
CONTRACT No.
PLATE NO. A-7

SUB-BOTTOM PROFILE POINTS

POINT	NORTHING	EASTING
1A	495892.99	1001229.50
18	513594.47	1013833.99
1C	497702.59	999798.71
10	513571.18	1011002.55
1E	499508.64	997895.96
1F	513548.20	1008171.08
1G	501318.43	996465.60
1H	513525.52	1005339.60
1I	573790	1514986
1J	562190	1506420
1K	576198	1512471
1L	564000	1504999
1M	577402	1511040
1N	571303	1507315
2A	481239.09	989530.44
28	495892.99	1001229.50
2C	482432.17	986686.65
20	497702.59	999798.71
2E	483632.31	984788.05
2F	499508.64	997895.96
2G	484832.59	982889.63
2H	501318.43	996465.60
3A	473932.78	986275.40
38	454513.54	986415.35
3C	454530.70	988780.29
30	473949.91	988638.58
3E	473967.25	991001.75
3F	454548.06	991145.25
3G	454565.63	993510.19
3H	467916.30	993410.32
4A	526218.06	998634.73
48	519568.14	1001988.72
4C	520186.12	1003399.35
40	526835.86	1000045.07
4E	527453.73	1001455.35

SUB-BOTTOM PROFILE POINTS

POINT	NORTHING	EASTING
4F	520804.17	1004809.91
4G	522029.17	1006215.54
4H	528075.40	1003337.20
4I	532345.94	1006133.14
4J	532945.28	1005185.17
4K	528667.47	1001445.87
4L	587602	1527559
4M	587602	1522217
4N	588894	1527797
40	588894	1523255
4P	590322	1528631
4Q	590322	1524106
4R	592022	1528614
4S	592022	1524718
4T	593671	1528648
4U	593671	1525365
4V	595353	1528818
4W	595353	1525960

BORING LOCATION

BORING No.	NORTHING	EASTING
01	580266	1497683
02	579900	1498439
3-A	579185	1499915
4-A	578515	1501302
05	577809	1502759
07	576798	1504848
08	576541	1505379
09	575678	1507161
10	574715	1509150
11	574127	1510365
12	573669	1511310
13	573168	1512345
14	572741	1513227
15	572297	1514145
16	571277	1516252
17	570916	1516999
18	570227	1518421
19	569643	1519627
20	568981	1520316
21	568297	1522408
22	567635	1523776
23	567269	1524532
24	566933	1525226
25	566654	1525802
26	570619	1517611
27	571944	1514875
28	572201	1514343
30	573434	1511796
31	576737	1504974
32	576717	1505014
33	577181	1504056
35	577329	1503749
36	578035	1502291
37	578820	1500671
38	579626	1499006

BORING LOCATION

BORING No.	NORTHING	EASTING
39	580227	1497764
40	580772	1496639
41	580504	1497192
42	580108	1498012
43	579469	1499331
44	579026	1500244
45	578652	1501018
46	578270	1501806
47	577580	1503232
48	576889	1504659
49	576321	1505833
50	576020	1506454
51	574436	1509726
52	575780	1506949
53	575410	1507714
54	575253	1508038
55	574894	1508781
56	573892	1510851
57	573467	1511729
58	572923	1512854
59	572513	1513700
60	572138	1514474
61	571615	1515554
62	575550	1507999
63	575100	1507781
64	571099	1516621
65	570417	1518029
66	569911	1519073
67	569310	1520316
68	568678	1521621
69	567988	1523048
70	567497	1524060
71	567197	1524681
72	567040	1525005
73	566724	1525658

USACE BORING LOCATION

BORING No.	NORTHING	EASTING
OH-8C-1	550828	1473827
OH-8C-2	550018	1474584
OH-8C-3	550111	1475695
OH-BC-4	549289	1476442
OH-8C-5	549404	1477558
OH-8C-6	548594	1478322
OH-8C-7	548688	1479435
OH-8C-8	547864	1480188
OH-8C-9	547985	1481294
OH-8C-10	547163	1482052
OH-8C-11	547274	1483165
OH-8C-12	546451	1483923
OH-8C-13	546569	1485045
OH-8C-14	545732	1485786
OH-8C-15	545852	1486911
OH-8C-16	545014	1487810
OH-8C-17	545125	1488772
OH-8C-18	544309	1489527
OH-8C-19	544415	1490639
OH-8C-20	543590	1491392
OH-8C-21	543711	1492509
OH-8C-22	542880	1493261
OH-8C-23	542988	1494375
OH-8C-24	542180	1495131
OH-8C-25	542284	1496253
OH-8C-26	541446	1497006
OH-8C-27	541562	1498111
OH-8C-28	540737	1498877
OH-8C-29	540845	1499988
OH-8C-30	540026	1500733
OH-BC-31	540035	1501847
OH-8C-32	539368	1502621
OH-8C-33	539889	1503895
OH-BC-34	538958	1503543
BB-1	550511	1473861

USACE BORING LOCATION

BORING No.	NORTHING	EASTING
88-2	549934	1475404
B8-3	549488	1477299
88-4	548252	1479033
88-5	547845	1480859
88-6	547864	1481506
B8-7	546174	1484581
88-8	545736	1486439
88-9	545187	1488387
88-10	544009	1490162
88-11	543596	1492125
88-12	543082	1494065
88-13	541972	1495666
88-14	541411	1497754
88-15	540912	1499717
88-16	539781	1501396
88-17	539364	1504164
CO-1	557002	1521365
CO-2	556566	1520454
CO-3	556133	1519558
CO-4	550450	1513581
CO-5	549502	1512746
CO-6	548650	1511992
CO-7	547767	1511270
CO-8	546834	1510472
CO-9	545941	1509696
CO-10	545049	1508926
CO-11	544162	1508159
CO-12	543249	1507393
CO-13	542362	1506624
CO-14	541438	1505804
CO-15	540571	1505100
CO-16	539619	1504439
CO-17	538749	1503840
CC100	501735	1488199
CC101	504776	1487046

USACE BORING LOCATION

BORING No.	NORTHING	EASTING
CC102	510759	1485037
CC103	512778	1484548
CC104	514774	1484522
CC105	516799	1484639
CC106	518718	1484639
CC107	520253	1484602
CC108	522677	1484531
CC109	524808	1484607
CC110	526685	1484607
CC111	529209	1484518
CC112	531292	1484380
CC113	532980	1483860
CC114	534708	1482928
CC115	537298	1481323
CC116	538725	1480404
CC117	540555	1479367
CC118	542706	1477944
CC119	546323	1475921
CC120	548141	1474905
CC121	547266	1475367
BA124	550752	1472461
BA125	551252	1470380
8S126	552706	1469142
BS127	553386	1467028
8S128	554099	1465429
8S129	554896	1463460
8S130	555612	1461220
BS131	556430	1459421
BS132	557227	1457416
8S133	558004	1455035
BS134	558269	1452611
8S135	560205	1449736
FM136	561715	1449076
FM137	562289	1447835
FM138	564270	1446996

USACE BORING LOCATION

BORING No.	NORTHING	EASTING
FM139	566188	1445340
FM140	567660	1445186
FM141	568656	1442429
FM142	570551	1440617
FM143	572285	1440393
FM144	573751	1439219
FM145	575251	1437924
FM146	576666	1436748
FM147	577501	1436169
FM148	579232	1434668
EC149	579937	1433800
EC150	583230	1432983
EC151	584103	1433006
EC152	585016	1432314
EC153	583840	1431908
EC154	584934	1431455
EC155	585117	1430485
EC156	586719	1429430
EC157	586763	1427405
C8158	566320	1436894
C8159	566349	1435986
CB160	566759	1434926
C8161	566397	1434027
C8162	567069	1432717
C8163	566460	1443432
CB164	566889	1442002
EC169	582975	1432376
EC170	582274	1433200
EC171	580117	1432955
EC172	578668	1435037
FM173	577726	1435049
FM174	575953	1437213
FM175	569975	1442333
FM176	568549	1443419
FM177	566244	1444211

USACE BORING LOCATION

BORING No.	NORTHING	EASTING
FM178	562552	1448322
BA179	559127	1451846
CU180A	547148	1475352
CU181A	543688	1477475
CU182	538083	1480869
CU183	541728	1478609
CU185	536035	1481964
C8186	566559	1432717
C8187	566330	1437894
C8188	566308	1434966
CU200	539551	1480019
C8201	566851	1433344
C8202	566951	1438619
C8203	566201	1434069
C8204	567344	1433120
C8205	567271	1432791
CB206	566219	1434038
C8207	567343	1432997
EC208	582273	1432477
EC209	582045	1432488
EC210	581951	1432489
FM211	577107	1435827
FM212	577951	1435131
C8213	567383	1433404
C8214	566865	1433844

EA SAMPLE LOCATION

SAMPLE No.	NORTHING	EASTING
A01-1	568929	1514568
A01-2	566880	1511199
A01-3	564181	1515392
A01-4	563047	1512724
A01-5	562635	1511862
A02-1	552384	1507531
A02-2	549826	1503692
A02-3	549144	1507319
A02-4	545977	1503169
A02-5	544779	1505304
A03-1	530102	1504389
A03-2	525218	1500721
A03-3	524852	1505847
A03-4	523515	1502940
A03-5	520286	1504147
A4A-1	592200	1527044
A4A-2	590588	1527922
A4A-3	586901	1522527
A4A-4	586617	1524888
A4A-5	584779	1522780
A48-1	587391	1520557
A48-2	585731	1515380
A48-3	584934	1516959
A48-4	585050	1518767
A48-5	582684	1513909

E2Si BORING LOCATION

BORING No.	NORTHING	EASTING
8-1-1	566215	1511273
B-1-2	560895	1511002
8-1-3	562369	1514004
8-1-4	567135	1514798
8-1-5	569758	1512506
S8-1-1	571474	1510722
S8-1-2	563859	1511910
S8-1-3	561756	1506093
C-1-1	569286	1510413
C-1-2	563416	1508810
C-1-3	558878	1513889
C-1-4	563911	1516278
C-1-5	569389	1515040
8-2-1	552638	1506875
B-2-2	546962	1504389
B-2-3	543886	1502129
B-2-4	543784	1504753
8-2-5	550082	1506034
C-2-1	551657	1503887
C-2-2	547683	1501761
C-2-3	542286	1504178
C-2-4	547682	1508126
C-2-5	551917	1508699
8-3-1	527574	1502116
8-3-2	522635	1500682

E2Si BORING LOCATION

BORING No.	NORTHING	EASTING
8-3-3	520657	1503283
8-3-4	525150	1505071
8-3-5	524433	1502584
C-3-1	529838	1503646
C-3-2	525718	1499727
C-3-3	518631	1501118
C-3-4	521914	1505871
C-3-5	526960	1506094
8-4A-2	589453	1525572
8-4A-3	587934	1527651
8-48-1	585542	1516104
8-48-2	583095	1513824

REV	DATE	DESCRIPTION	BY

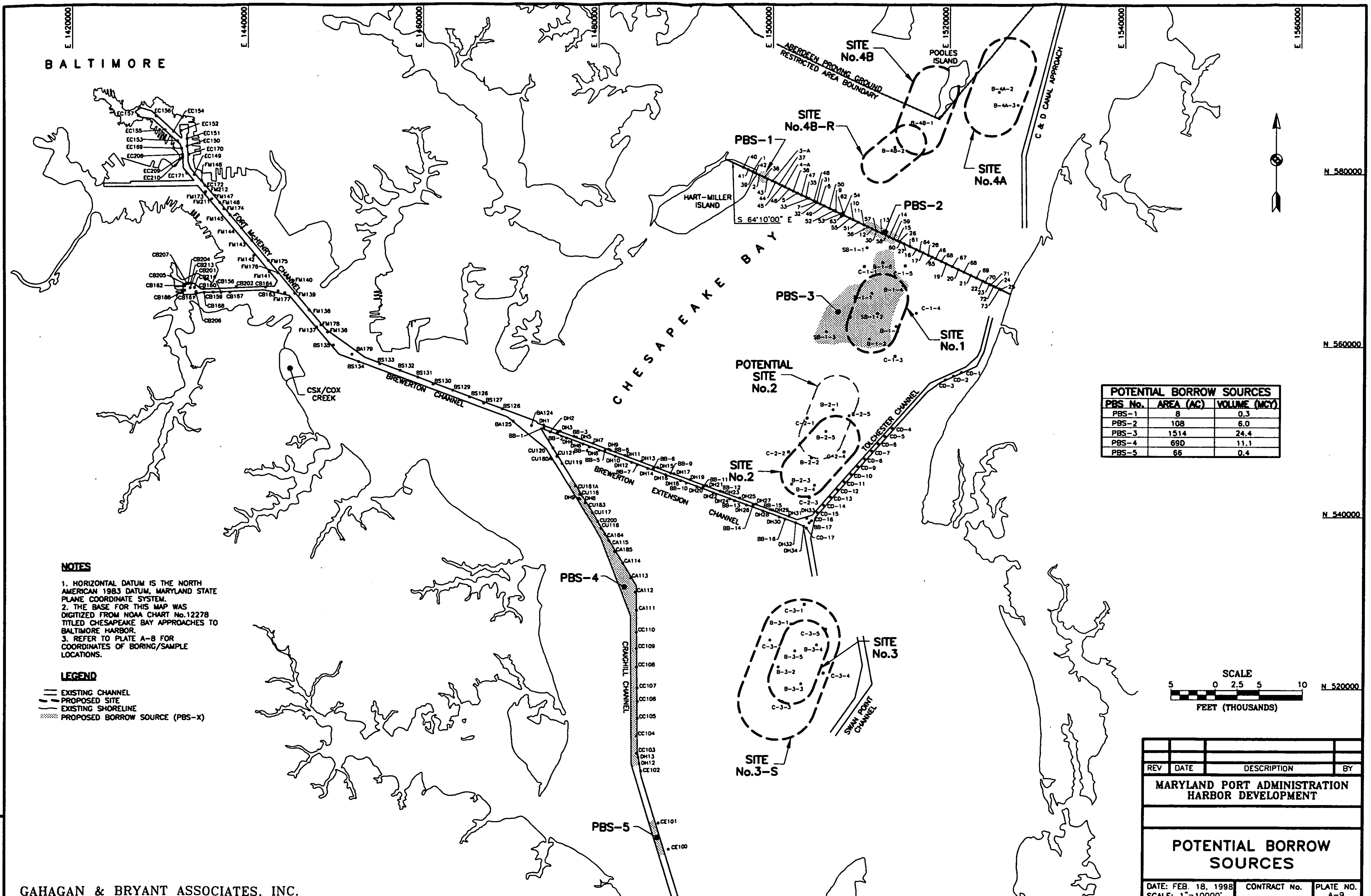
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

EXISTING GEOTECHNICAL DATA COORDINATES

DATE: FEB. 18, 1998 | CONTRACT No. | PLATE NO. A-8
SCALE: N/A

DESIGNED BY: ____
DRAWN BY: ____

GAHAGAN & BRYANT ASSOCIATES, INC.



NOTES

1. HORIZONTAL DATUM IS THE NORTH AMERICAN 1983 DATUM, MARYLAND STATE PLANE COORDINATE SYSTEM.
2. THE BASE FOR THIS MAP WAS DIGITIZED FROM NOAA CHART No.12278 TITLED CHESAPEAKE BAY APPROACHES TO BALTIMORE HARBOR.
3. REFER TO PLATE A-8 FOR COORDINATES OF BORING/SAMPLE LOCATIONS.

LEGEND

- EXISTING CHANNEL
- PROPOSED SITE
- EXISTING SHORELINE
- PROPOSED BORROW SOURCE (PBS-X)

POTENTIAL BORROW SOURCES

PBS No.	AREA (AC)	VOLUME (MCY)
PBS-1	8	0.3
PBS-2	108	6.0
PBS-3	1514	24.4
PBS-4	690	11.1
PBS-5	66	0.4

REV	DATE	DESCRIPTION	BY

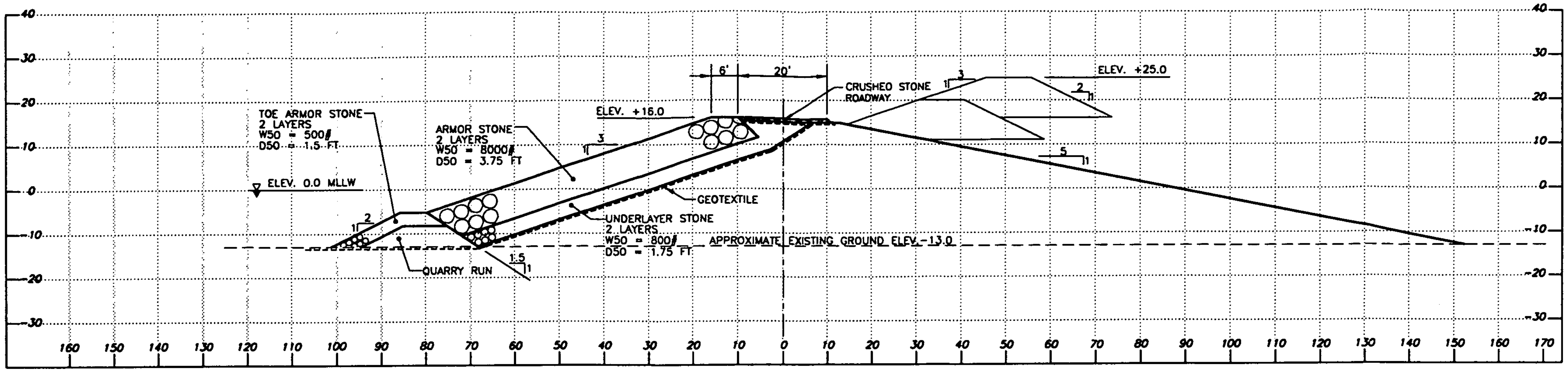
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

POTENTIAL BORROW SOURCES

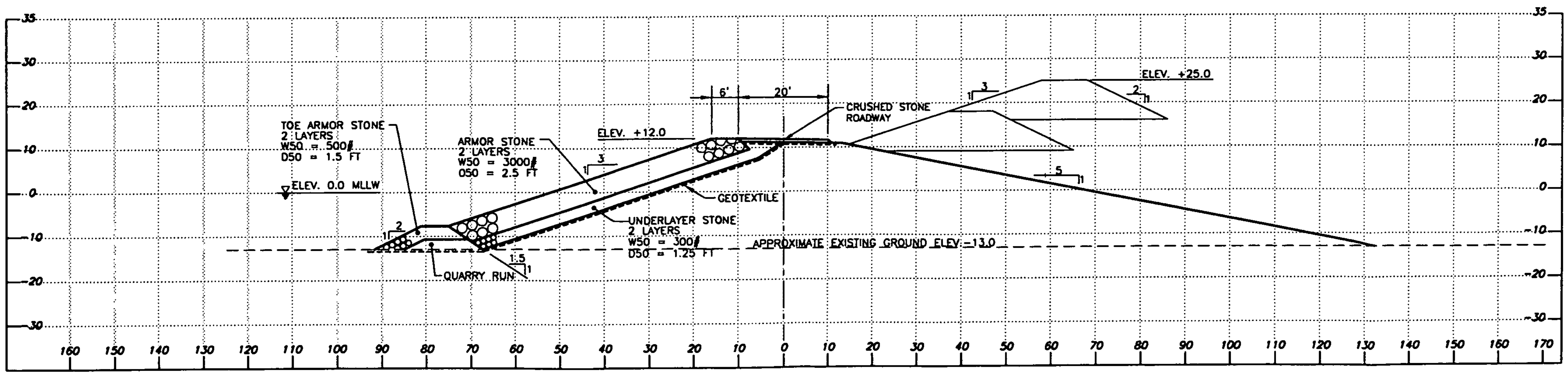
DATE: FEB. 18, 1998 | SCALE: 1"=10000' | CONTRACT No. | PLATE NO. A-9

DESIGNED BY: RKM
DRAWN BY: TMD

GAHAGAN & BRYANT ASSOCIATES, INC.



TYPICAL DIKE SECTION 1-A



TYPICAL DIKE SECTION 1-B

NOTES:

1. FOR ALTERNATIVE 1-2, THE DIKES WILL BE INCREMENTALLY RAISED TO ELEVATION +35 FT.
2. FOUNDATION DISPLACEMENT DURING CONSTRUCTION IS NOT SHOWN.

LEGEND

- EXISTING GROUND
- PROPOSED DIKE
- GEOTEXTILE
- FUTURE DIKE RAISING

SCALE
15 0 7.5 15 30
FEET

REV	DATE	DESCRIPTION	BY

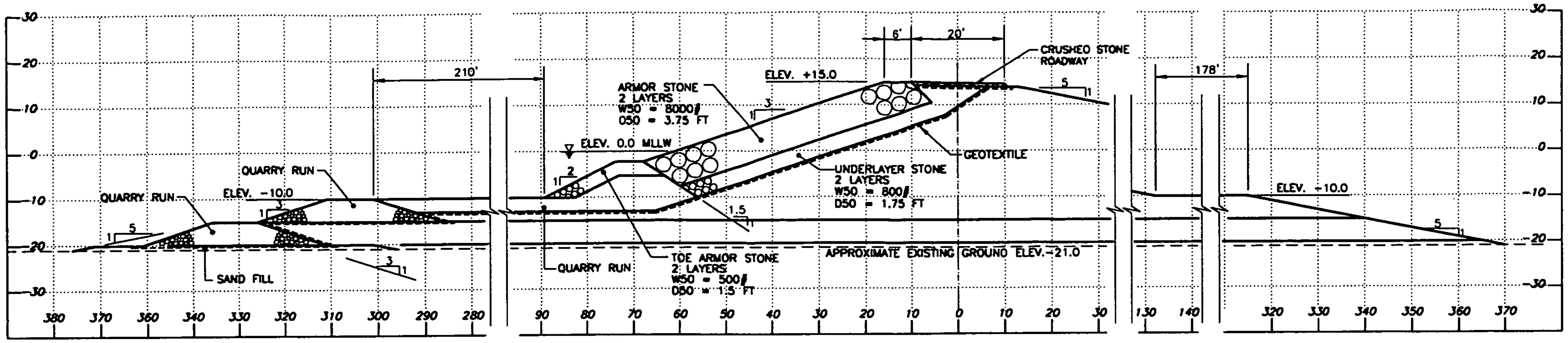
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

SITE NO. 1
DIKE SECTIONS 1-A & 1-B

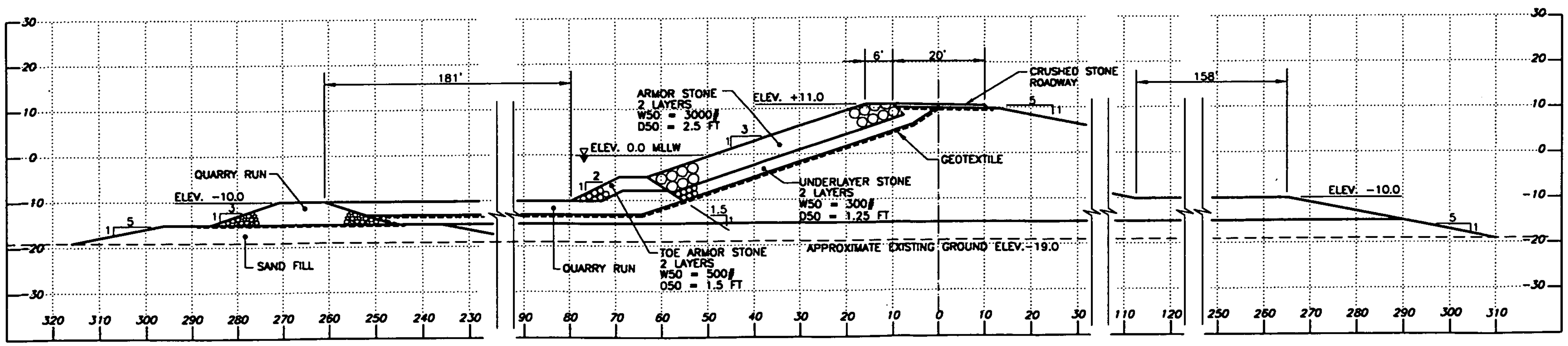
DATE: FEB. 18, 1998 | SCALE: 1"=30' | CONTRACT No. | PLATE NO. A-10

DESIGNED BY: RKM
DRAWN BY: TMD

GAHAGAN & BRYANT ASSOCIATES, INC.



TYPICAL DIKE SECTION 2-A



TYPICAL DIKE SECTION 2-B

NOTES:

1. FOR ALTERNATIVE 2-2, THE DIKES WILL BE INCREMENTALLY RAISED TO ELEVATION +18 FT.

2. UNDERCUTTING AND FOUNDATION DISPLACEMENT DURING CONSTRUCTION ARE NOT SHOWN.

LEGEND

- EXISTING GROUND
- PROPOSED DIKE
- GEOTEXTILE

SCALE 15 0 7.5 15 30 FEET

DESIGNED BY: RKM
DRAWN BY: TMD

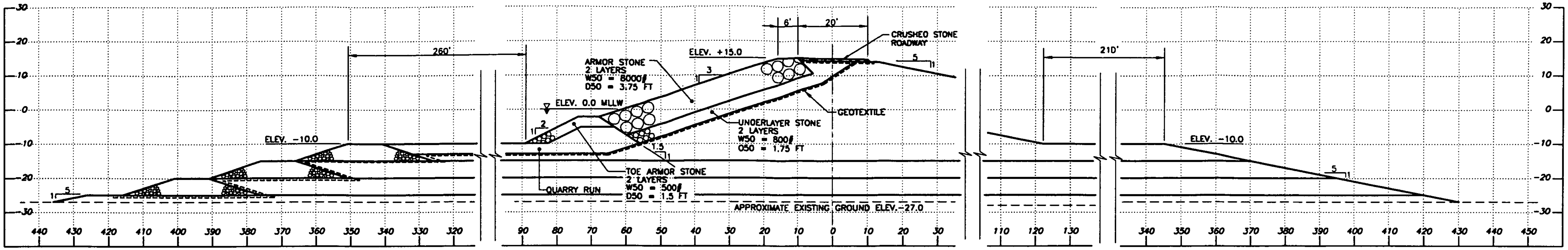
GAHAGAN & BRYANT ASSOCIATES, INC.

REV	DATE	DESCRIPTION	BY

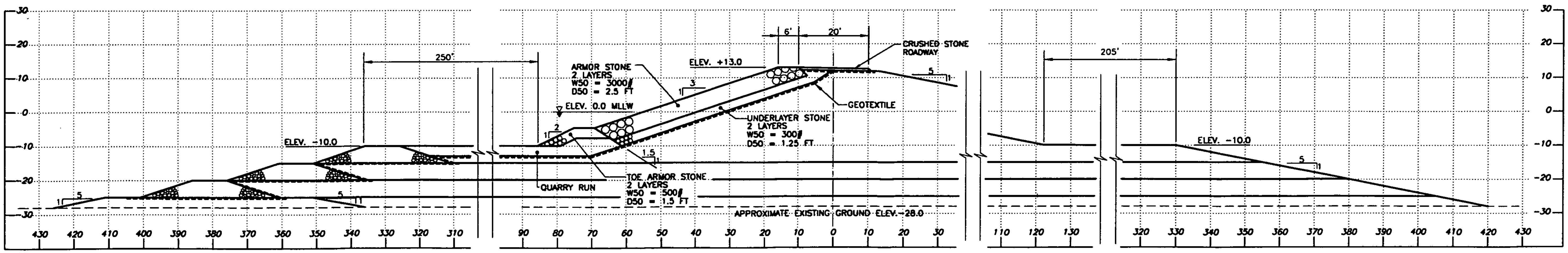
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

SITE NO. 2
DIKE SECTIONS 2-A & 2-B

DATE: FEB. 18, 1998 SCALE: 1"=30' | CONTRACT No. | PLATE NO. A-11



TYPICAL DIKE SECTION 3-A



TYPICAL DIKE SECTION 3-B

NOTES:

1. FOR ALTERNATIVE 3-2, THE DIKES WILL BE INCREMENTALLY RAISED TO ELEVATION +18 FT.

2. UNDERCUTTING AND FOUNDATION DISPLACEMENT DURING CONSTRUCTION ARE NOT SHOWN.

LEGEND

- -- EXISTING GROUND
- — PROPOSED DIKE
- --- GEOTEXTILE

SCALE

15 0 7.5 15 30

FEET

REV	DATE	DESCRIPTION	BY

MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

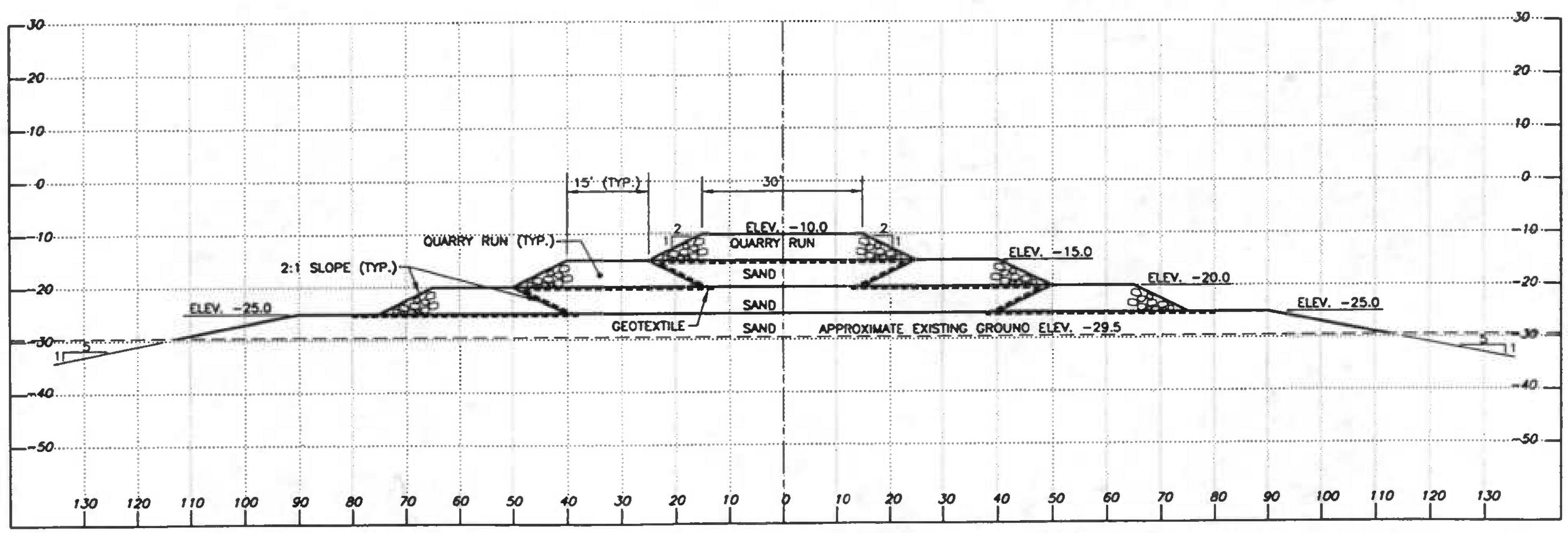
SITE NO. 3
DIKE SECTIONS 3-A & 3-B

DATE: FEB. 18, 1998 SCALE: 1"=30'	CONTRACT No.	PLATE NO. A-12

DESIGNED BY: RKM
DRAWN BY: TMD

GAHAGAN & BRYANT ASSOCIATES, INC.

Site 3-S X-Sect.



TYPICAL DIKE SECTION 3-S

LEGEND

- Existing Ground
- Proposed Dike
- Geotextile

SCALE 15 0 7.5 15 30 FEET

NOTE:

FOUNDATION DISPLACEMENT DURING CONSTRUCTION IS NOT SHOWN.

REV	DATE	DESCRIPTION	BY

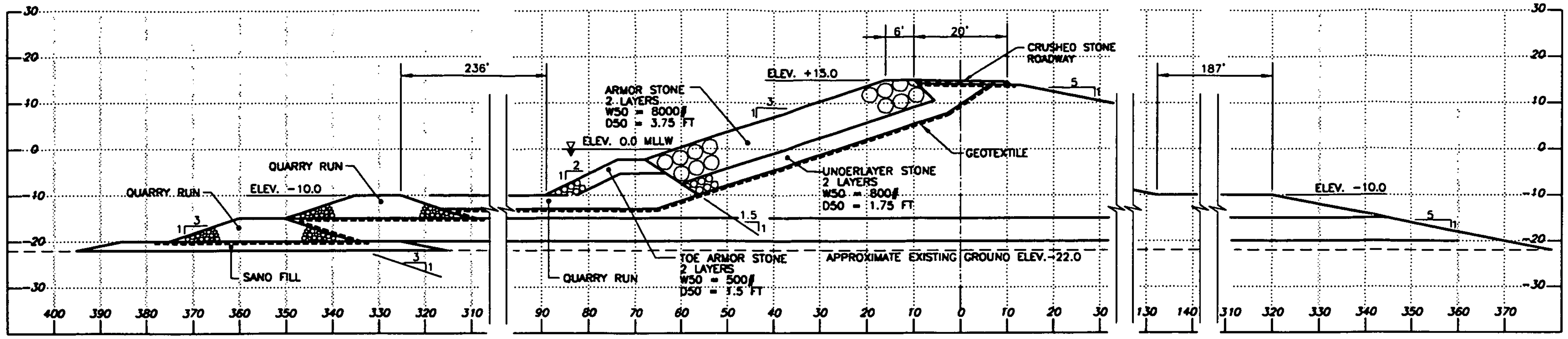
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

SITE NO. 3-S
DIKE SECTION

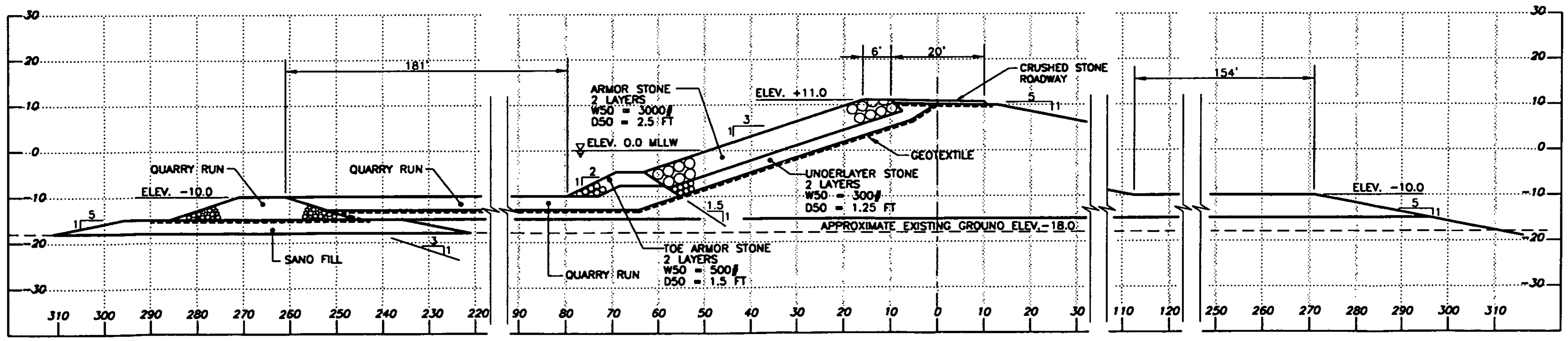
DATE: FEB. 18, 1998 SCALE: 1"=30' | CONTRACT No. | PLATE NO. A-13

DESIGNED BY: RKM
DRAWN BY: TMD

GAHAGAN & BRYANT ASSOCIATES, INC.



TYPICAL DIKE SECTION 4A-A



TYPICAL DIKE SECTION 4A-B

NOTES:

1. FOR ALTERNATIVE 4A-2, THE DIKES WILL BE INCREMENTALLY RAISED TO ELEVATION +18 FT.

2. UNDERCUTTING AND FOUNDATION DISPLACEMENT DURING CONSTRUCTION ARE NOT SHOWN.

LEGEND

- — — EXISTING GROUND
- ——— PROPOSED DIKE
- - - - GEOTEXTILE

SCALE
15 0 7.5 15 30
FEET

REV	DATE	DESCRIPTION	BY

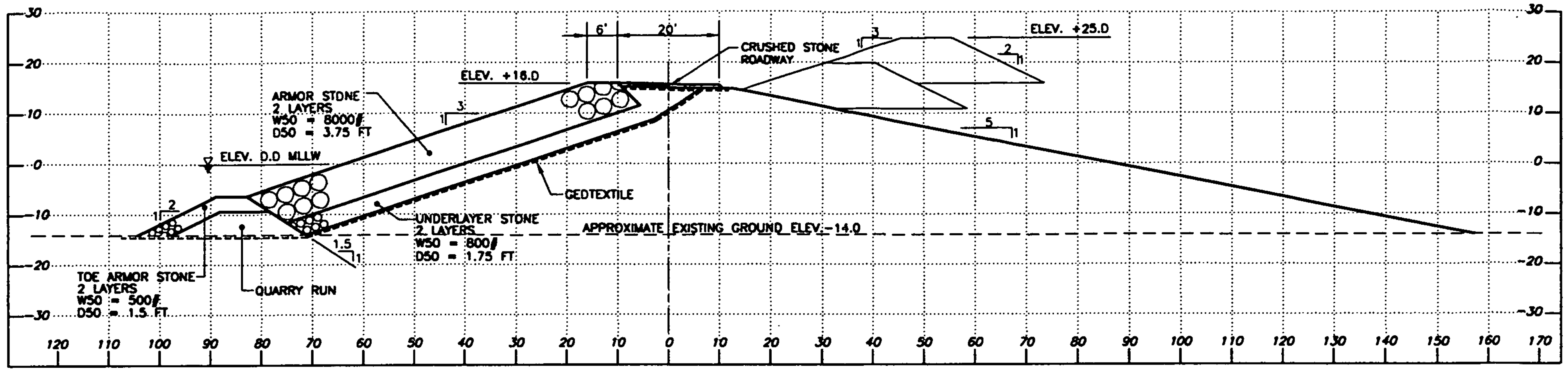
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

SITE NO. 4A
DIKE SECTIONS 4A-A & 4A-B

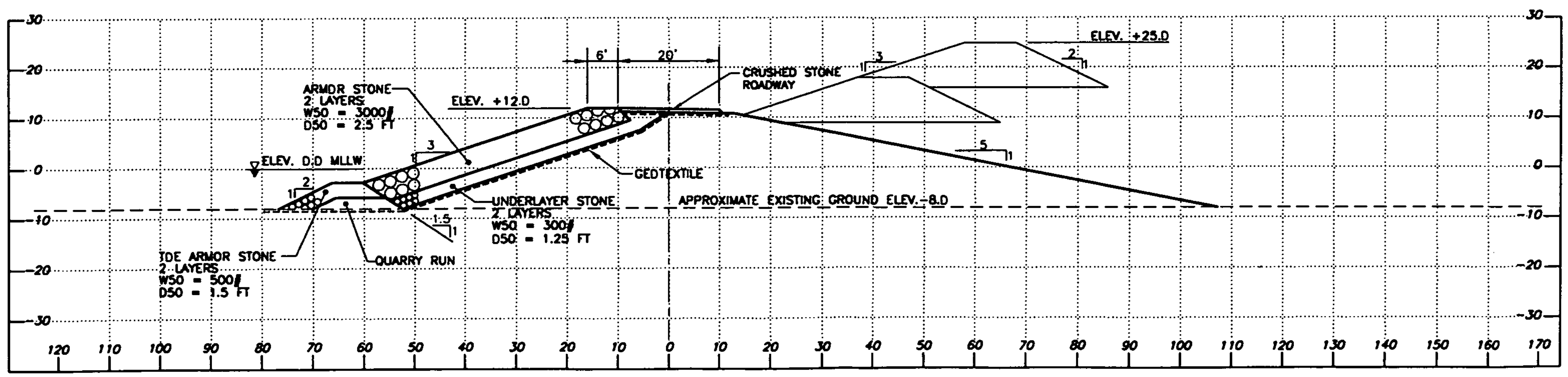
DATE: FEB. 18, 1998
SCALE: 1"=30'
CONTRACT No.
PLATE NO. A-14

DESIGNED BY: RKM
DRAWN BY: TMD

GAHAGAN & BRYANT ASSOCIATES, INC.



TYPICAL DIKE SECTION 4B-A



TYPICAL DIKE SECTION 4B-B

LEGEND

- EXISTING GROUND
- PROPOSED DIKE
- GEOTEXTILE
- FUTURE DIKE RAISING

SCALE

15 0 7.5 15 30

FEET

NOTES:

1. FOR ALTERNATIVE 4B-2, THE DIKES WILL BE INCREMENTALLY RAISED TO ELEVATION +35 FT.
2. FOUNDATION DISPLACEMENT DURING CONSTRUCTION IS NOT SHOWN.

DESIGNED BY: RKM
DRAWN BY: TMD

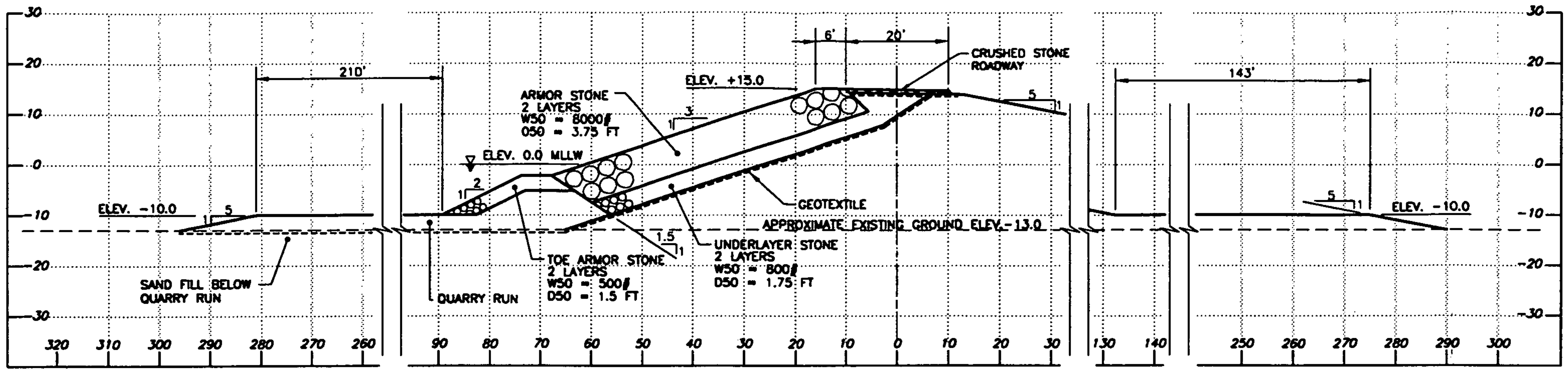
GAHAGAN & BRYANT ASSOCIATES, INC.

REV	DATE	DESCRIPTION	BY

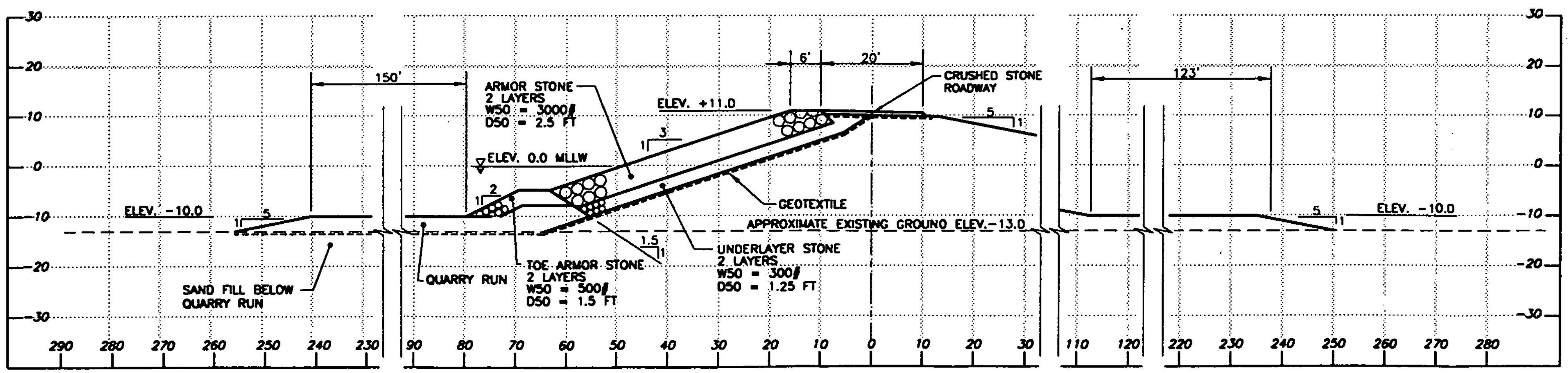
MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

SITE NO. 4B
DIKE SECTIONS 4B-A & 4B-B

DATE: FEB. 18, 1998 SCALE: 1"=30'	CONTRACT No.	PLATE NO. A-15



TYPICAL DIKE SECTION 4B-R-A



TYPICAL DIKE SECTION 4B-R-B

NOTES:

1. FOR ALTERNATIVE 4A-2, THE DIKES WILL BE INCREMENTALLY RAISED TO ELEVATION +18 FT.
2. UNDERCUTTING AND FOUNDATION DISPLACEMENT DURING CONSTRUCTION ARE NOT SHOWN.

LEGEND

- – – EXISTING GROUND
- —— PROPOSED DIKE
- - - - GEOTEXTILE

SCALE

15 0 7.5 15 30

FEET

REV	DATE	DESCRIPTION	BY

MARYLAND PORT ADMINISTRATION
HARBOR DEVELOPMENT

SITE NO. 4B-R
DIKE SECTIONS 4B-R-A & 4B-R-B

DATE: FEB. 18, 1998 SCALE: 1"=30' | CONTRACT No. | PLATE NO. A-16

DESIGNED BY: ___ DRAWN BY: TMD

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APPENDIX B
GEOPHYSICAL INVESTIGATION REPORT

Department of Natural Resources
Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

COASTAL AND ESTUARINE GEOLOGY

FILE REPORT NO. 97-6

Preliminary Report on Bottom and Sub-bottom Sediment Characteristics at 5 Proposed Island Creation Sites

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INTRODUCTION

Dredging and placement of dredged sediment is a continuing need for maintaining open navigation channels to and from the Port of Baltimore. The Maryland Port Administration (MPA) is responsible for coordinating these activities to insure the continued viability of the Port. The MPA has been charged with conducting a pre-feasibility study of potential sites to address the long-term dredging needs in the northern portion of the Chesapeake Bay. To accommodate these needs the creation of an island containment facility for clean dredged sediments has been proposed and the pre-feasibility study is examining various site options.

At the present time, five sites are under consideration for the development of a contained sediment placement facility in the upper Bay. As part of the pre-feasibility study of these sites, the MPA contracted with the Coastal and Estuarine Geology project of the Maryland Geological Survey to conduct an acoustic remote sensing survey in the area, and to collect bottom sediment samples to provide ground truth data for the acoustic information. These data were not meant to definitively describe the geological and morphological characteristics of the sites under review, but to provide a preliminary assessment of conditions in the area. In addition, the acoustic data was intended to be useful for the environmental assessment of the areas, and for identifying and correlating bottom sediment geotechnical information collected by other contractors as part of the pre-feasibility study.

METHODS

Four of the five potential dredged sediment island creation sites were surveyed using acoustic methods on 13 and 19 March 1997. The system utilized was a combined Edgetech Chirp Sub-bottom Profiler and Side-scan Sonar system. The sub-bottom system operated across a frequency range of 2 kHz to 15 kHz with a pulse length of 5 milliseconds. Maximum sub-bottom penetration of 15 meters was achieved where bottom conditions were suitable. Generally, sub-bottom records were obtained up to 3 to 4 meters below the sediment water interface. The side-scan survey system was operated at both 200 and 500 kHz. However, the higher frequency setting did not yield good results due to the high concentration of suspended sediment prevalent in this portion of the Chesapeake Bay, and prints of the records were not produced. The side-scan system was set to survey a swath 75 meters to either side of the boat track. These surveys were meant to be reconnaissance in nature and complete coverage of the bottom was not attempted. All data was stored digitally on tape and archived.

In acoustic surveying techniques outgoing sound pulses generated by the profiling units are directed toward the bay bottom. The sub-bottom signal is directed straight downward toward the bottom while the side-scan signals are generated at an angle on either side of the equipment. A portion of the outgoing acoustic energy is reflected back to the survey equipment when interfaces are encountered across which there are velocity-density contrasts. The primary contrast is generated at the sediment-water interface where most of the incident energy reflects back to the equipment (Trabant, 1984). The strength of the return signal(s) is dependent on the bottom sediment type, bottom topography and roughness, and the angle of acoustic wave incidence among other factors.

Four tracklines were initially established and run in the vicinity of four of the five proposed island creation sites (Figure 1). However, because the locations of the sites had not been firmly established at the time the survey was conducted, the surveyed areas generally extended well beyond the eventual limits of the sites. Area 4-B was not completely surveyed because the shallow waters in the vicinity of Pooles Island prevented vessel access. Area 4-B-R was not completely surveyed because its location and limits were established late in the site analysis process. Area 4-A was not included in the survey because of the extensive use of much of this area for the open-water placement of dredged sediment in the past and the existence of data from a previously conducted survey in the area. The survey of 4-A was conducted in August 1996 and utilized a Datasonics 5.0 kHz sub-bottom profiling system operating with a 5 millisecond pulse length. Paper records from this survey are archived at the Maryland Geological Survey.

The Datasonics system was also utilized on 25 June 1997 to collect data along three additional tracklines to the northwest of those originally collected in the vicinity of Area 1. By this date the potential location of the site was more firmly established and the additional lines were run to insure that preliminary data was available within the footprint of the potential site location.

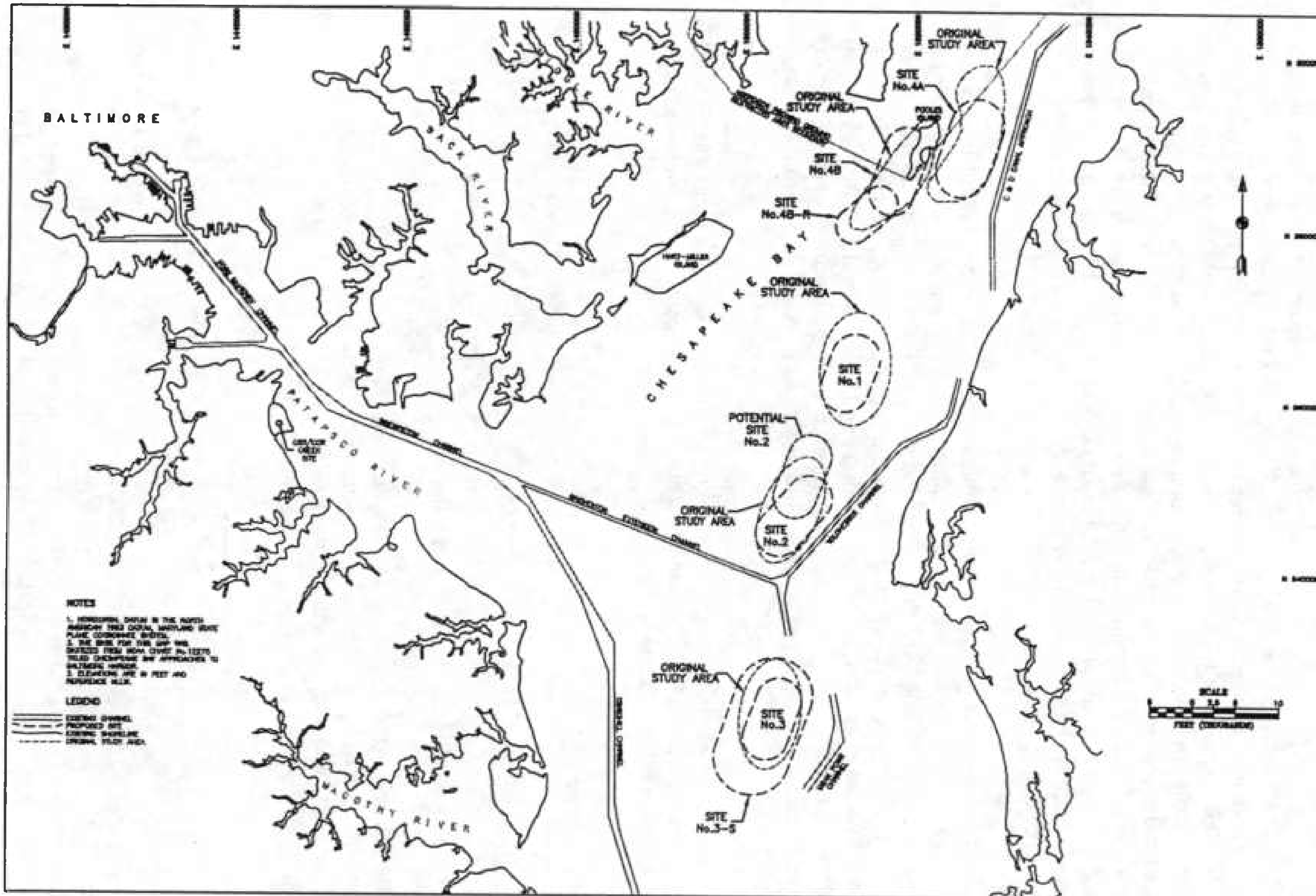

Figure 1: Location map of the pre-feasibility study areas.

Ground truth of the surficial sediment characteristics was established through the collection of 49 surficial sediment samples on 25 June 1997 in all sites except Area 4-A. These sampling sites were established to cover a range of bottom types identified on the side-scan surveys. Surficial samples of the bottom sediment were collected with a dip-galvanized Petersen grab sampler. Once on board each sediment sample was described and the upper 2 - 4 cm subsampled and placed in Whirl-Pak plastic bags. All samples were refrigerated prior to returning to the laboratory for further analysis. Grain size analyses were conducted according to MGS standard techniques as outlined in Kerhin and others (1988). These analyses were identical to those carried out by the Maryland Geological Survey in previous studies of surficial sediment types in the Chesapeake Bay.

Laboratory analysis of the sediment samples consisted of determining water content and the percentages of sand, silt and clay in the samples. These data and field descriptions of the sediment samples are included in Table I, included at the end of the text portion of this report. Core data, to provide ground truth for the sub-bottom records, was not collected. However, the records were utilized to assist in locating the boring and CPT sites occupied by E2SI as part of the overall pre-feasibility study. The following report provides a summary of the conditions encountered in each of the surveyed areas and presents representative side-scan and sub-bottom records in the sites.

Water content was determined by the following procedure. A 30 g sub-sample was weighed accurately, dried at 65 °C, and then reweighed. Water content was calculated as the percentage of water weight to the total weight of wet sediment, as follows:

$$\% H_2O = \left(\frac{W_w}{W_t}\right) \times 100 \tag{1}$$

where W_w is the weight of water, and W_t is the weight of wet sediment.

Bulk density (ρ_b) was calculated from water content utilizing equation (2), assuming an average grain density (ρ_s) of 2.72 g/cm^3 and saturation of voids with water of density ρ_w = 1.0 g/cm^3. This method was adopted from the work of Bennett and Lambert (1971):

$$\rho_b = \frac{W_t}{W_d/2.72 + W_w} \tag{2}$$

where W_d is the weight of dry sediment.

Grain-size analysis consisted of cleaning the samples in solutions of 10 percent hydrochloric acid and 15 percent hydrogen peroxide with subsequent rinsing with deionized water. This process removed soluble salts, carbonates, and organic matter that could interfere with the disaggregation of the individual grains. The samples were then treated with a 0.26 percent solution of the dispersant sodium hexametaphosphate ($(NaPO_3)_6$) to ensure that individual grains did not reaggregate during analysis.

The separation of sand and silt-clay portions of the sample was accomplished by wet-sieving through a 4-phi mesh sieve (0.0625 mm, U.S. Standard Sieve #230). The sand fraction was dried and weighed. The finer silt and clay sized particles were suspended in a 1000 ml cylinder in a solution of 0.26 percent sodium hexametaphosphate. The suspension was agitated and, at specified times thereafter, 20 ml pipette withdrawals were made (Carver, 1971; Folk, 1974). The rationale behind this process is that larger particles settle faster than smaller ones. By calculating the settling velocities for different sized particles, times for withdrawal can be determined at which all particles of a specified size will have settled past the point of withdrawal. Sampling times were calculated to permit the determination of the amount of silt and clay sized particles in the suspension. Withdrawn samples were dried at 60°C and weighed. From these data the percentages by dry weight of sand, silt, and clay were calculated for each sample and classified according to Shepard's (1954) nomenclature.

Navigation for both the acoustic surveys and the bottom grab sampling was accomplished using a Magnavox 300 survey-grade Differential Global Positioning System (DGPS). Differential corrections broadcast by the Coast Guard provided a horizontal accuracy of 2-5 meters. All navigation data were logged to an on board computer.

RESULTS

Area 1

The most significant feature of Area 1 is the large shoal located west of Tolchester Beach on which water depths generally are less than 12 to 14 feet. The surveyed tracklines traversed most of the shoal and covered portions of the area to the east and to the northeast, as well as to the west. The four southeastern most lines were run with the Chirp profiling system, and included both side-scan and sub–bottom profiling. The northwestern three lines were run with the Datasonics system, which provided only sub-bottom information. A number of surficial grab samples were collected on top of and around the shoal area (Figure 2).

The grab sample data indicates that most of the surface of the shoal consists of sand sized sediments in which the sand sized component exceeds 90% (Table I). Various admixtures of shells were present in most of the samples and included the species *Macoma baltica, Rangia cuneata and Crassostrea virginica.* At two of the sampling stations (20 and 25) located on the eastern side of the shoal, the bottom consisted entirely of disarticulated and broken oyster shell (*C. Virginica*). No sediment could be collected at these stations for grain size analysis due to the presence of the shell.

Much of the bottom over the top of the shoal is smooth and flat as shown on the side-scan record made at sampling station 13 (Figure 3). Sediments at this station consisted of over 95% sand. Along some of the shoal edges, in slightly deeper water, shallow relief sand waves were present as exhibited on the side-scan record from station 19 (Figure 4). These are probably transient features with amplitude and orientation determined by the preceding wind/wave climate in the area, and attest to the dynamic conditions on the bottom. Alternatively, they could be the result of the wakes from ship passage in the adjacent channel.

In certain areas of the shoal drag marks were present on the bottom which were interpreted to resulted from either soft clam or oyster dredging activities (Figure 5, lower half of record). This figure is located at sampling station 12 where the bottom consisted of only 36% sand with the remainder composed of finer grained muds. The presence of a higher percentage of silt and clay sized particles in bottom sediments from areas where these markings occur may serve to either improve the habitat for infaunal molluscs, increase the effectiveness of dredging activities, and/or preserve the drag marks in the bottom sediments. All of these factors could contribute to the occurrence and preservation of dredging activity marks in certain portions of Area 1. Side-scan coverage was, however, not complete enough to thoroughly map the presence of these marks, and determine the extent of shell harvesting activities in Area 1.

The bottom sediments surrounding the shoal area consist of typical estuarine muds wherever the water depths generally exceed 12 to 14 feet. These muds have a very low percentage of sand sized particles (<5%) and generally consist of sub-equal proportions of silt and clay sized particles (Table I). Low numbers of shells are commonly present in these muddy sediments and include *Macoma baltica, and Rangia cuneata.* The sub-bottom records indicate that the sands comprising the shoal dip steeply below the surrounding muddy sediments (Figure

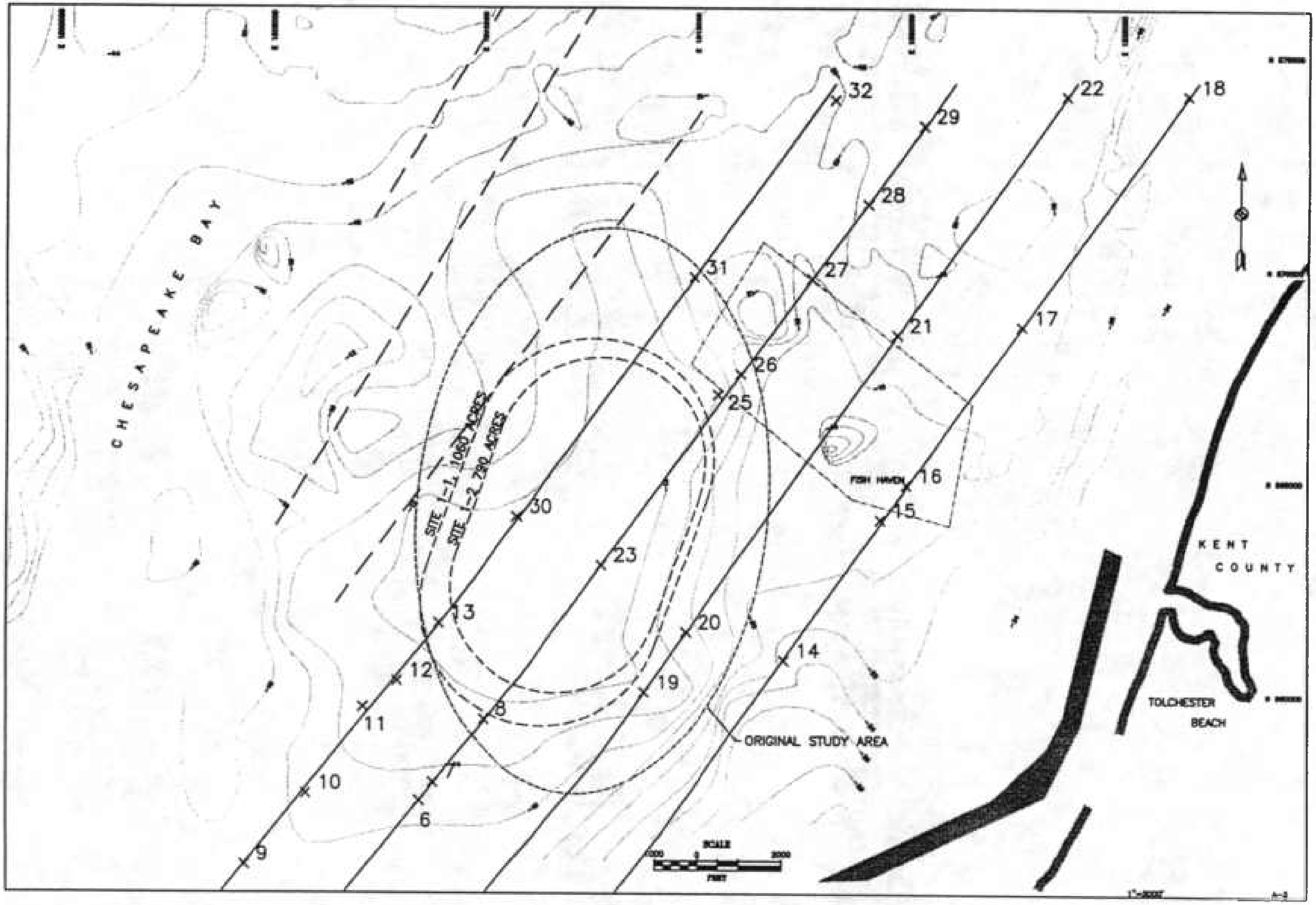

Figure 2: Study Area No. 1 with acoustic tracklines and sediment sampling sites. Solid tracklines run with Edgetech Chirp System, dashed tracklines run with Datatsonics System.

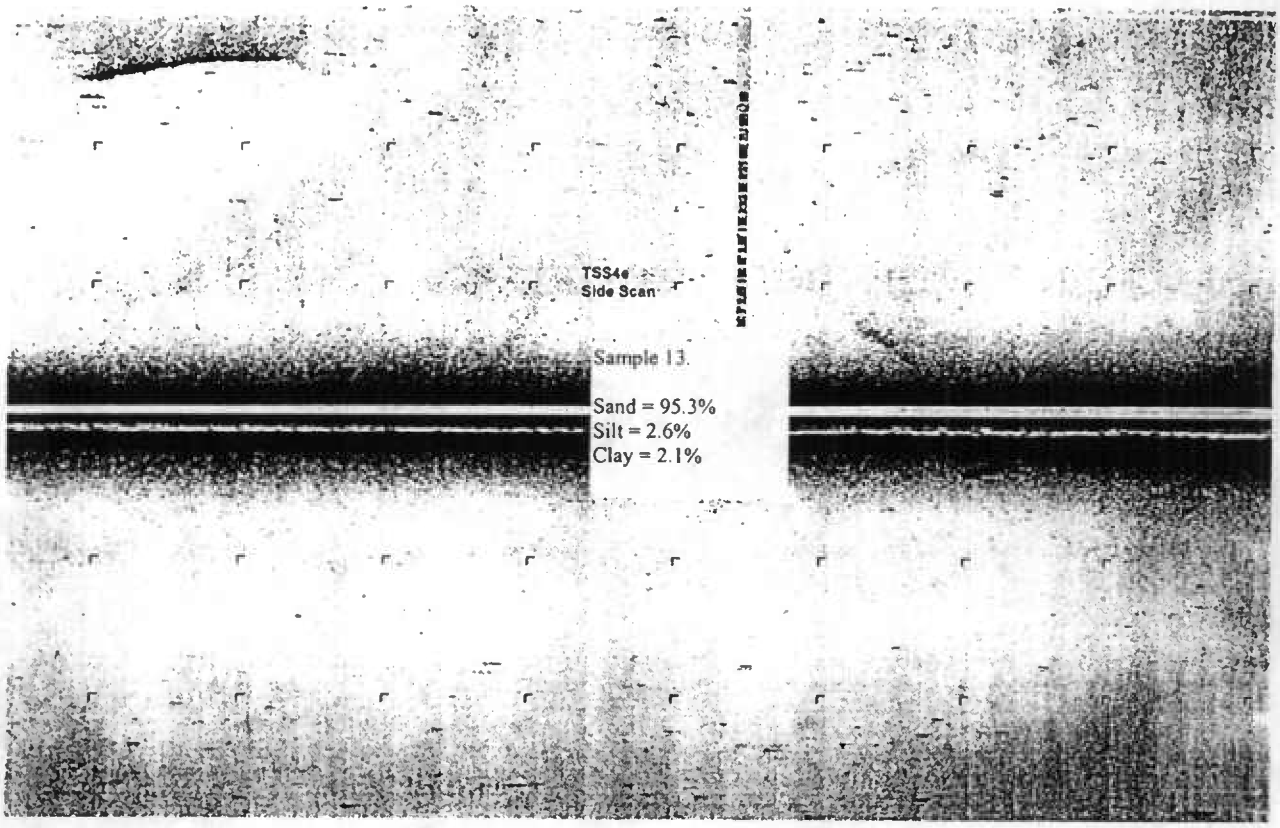

Figure 3: Side-scan sonar image taken on the top of the sand shoal in Area 1, at the location of Surficial sample number 13. Note the mostly featureless smooth and flat bottom in the area. The identity of the dark linear feature in the upper left of the image is uncertain. It is most likely a small scarp or cut in the bottom with a distinct side facing the sonar source.

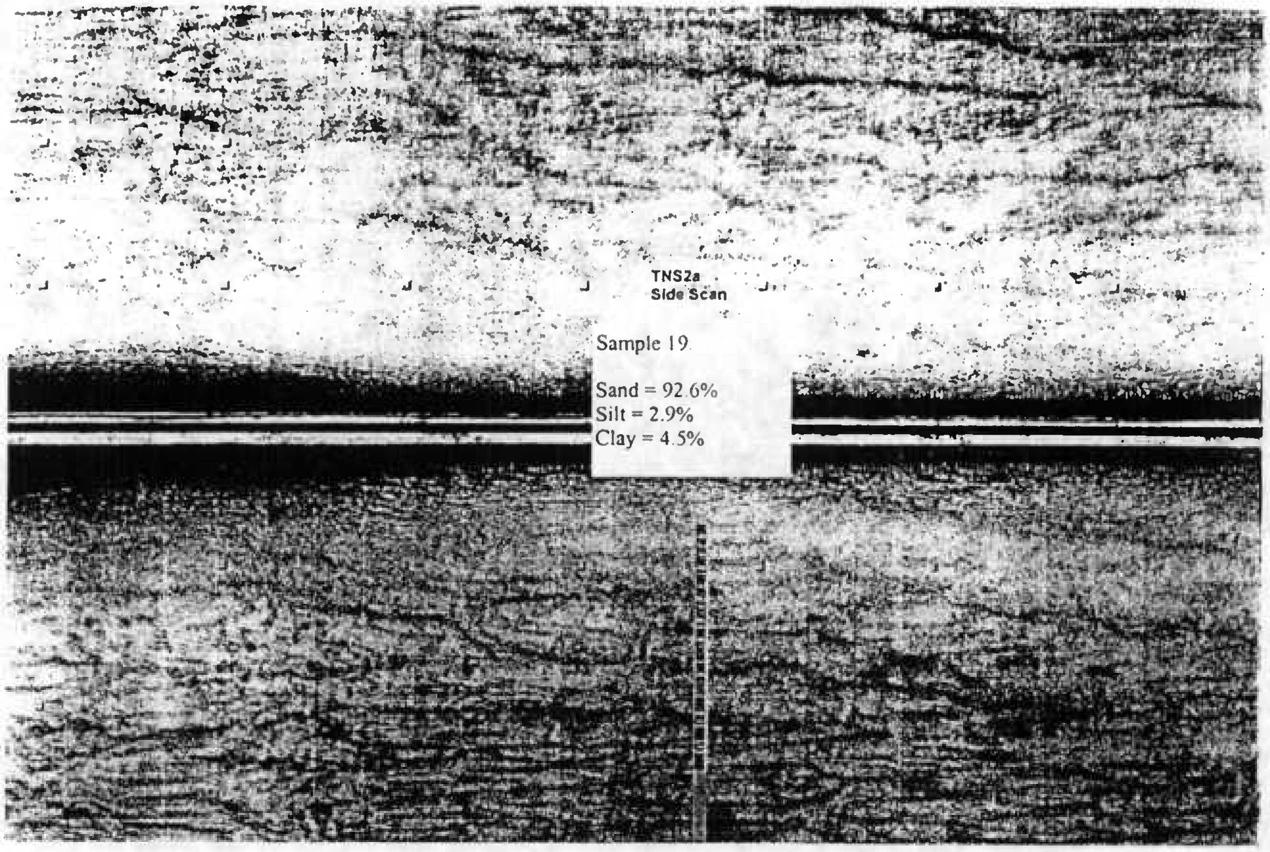

Figure 4: Side-scan sonar image taken on the top of the sand shoal in Area 1, at the location of surficial sediment sample 19. The field description for this sample indicated that some shell was present in the sediment. The patterns oriented roughly parallel to the track of the vessel are probably produced by low relief sand waves that move across this part of the shoal under the influence of wind generated waves or ship's wakes.

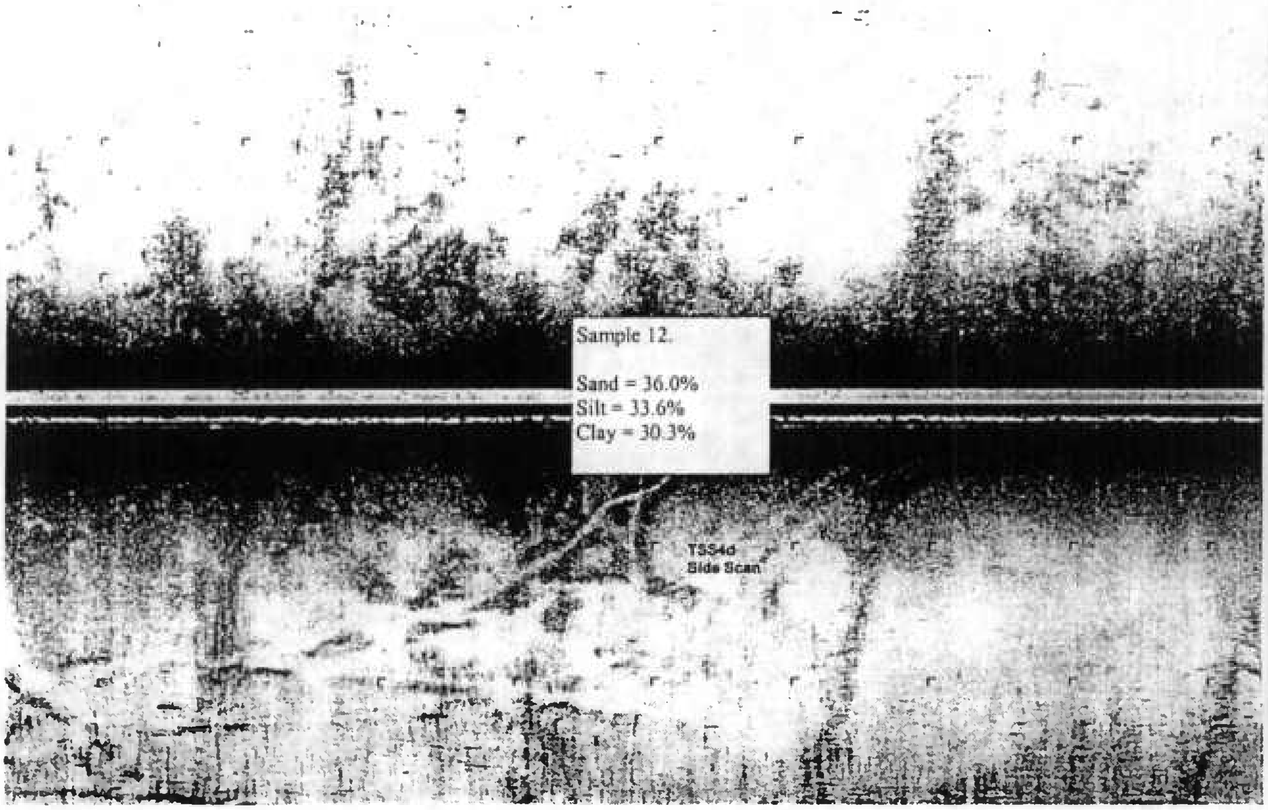

Figure 5: Side-scan sonar image taken on the southwest side of the shoal in Area 1, at the location of surficial sediment sample 12. The sample desciption indicated that numerous shells were present in this area. The sinuous surface marks present in the bottom center portion fo the record are interpreted to be the result of shellfish dredging activity.

6). The characteristics of the estuarine muddy sediments will be covered in more detail below in the discussion of Areas 2 and 3.

In the northeastern most section of Area 1 and portions of the charted "Fish Haven" located to the northeast (Figure 2), intensive "fossil" oyster shell dredging took place in the mid to late 1980's (C. Judy, Department of Natural Resources, personal communication). Evidence of this activity was observed on the side-scan and sub-bottom records in the vicinity of bottom sediment stations 15-16, and 25-26, and in the immediate area (Figure 2). The shell dredging activity consisted of excavating portions of the bottom in which there was a high percentage of old oyster shell. This activity produced a variable bottom relief in the area that was dredged consisting of remnant high spots and excavated trenches. In portions of the area the dredging cuts have been partially filled with fine grained muddy sediments. The activities produced relief of 7 to 10 feet in the vicinity of stations 15, 16, 25 and 26. Evidence of similar activity was noted in the sub-bottom record from the northern portion of Line 6, collected with the Datasonics profiling unit. No side-scan records, that could provide evidence of the lateral extent of the activities, were collected along this line.

The question has been raised as to whether or not an island existed on this shoal area at some point in the past. To explore this question a number of historical charts and maps of the Chesapeake Bay were examined for evidence of an island in the vicinity. These included the maps of John Smith (1608), Augustine Hermann (1670), Joshua Fry and Peter Jefferson (1751), Anthony Smith (1776), and the U.S. Coast Survey chart produced in the 1840's. Given the nature of these maps the presence and location of islands (and other features) is always open to some question. However, none presented any evidence for an island in the vicinity of this shoal. In comparison, they did clearly show or name Pooles Island located to the northwest, evidence for the capabilities of these mapmakers. The U.S. Coast Survey Chart shows depths in the area in the range of 9-12 feet in the 1840's, approximately the same as shown on present day NOS charts. Based on the review of these charts there is no compelling evidence that an island was present at the location of the shoal in Area 1 since the time of European exploration of the Chesapeake area and the production of reasonably accurate maps.

However, sea level has been rising in the Chesapeake area for the past 18,000 years and it is certain that an island was exposed at this location at some time in the past. Water depths over the area are presently charted in the range of 9-12 feet as indicated above. Using the most recent sea level rise curve for the Chesapeake Bay area (Colman et al., 1992) sea level stood some 10 feet lower approximately 2,000 years ago. This represents an "upper" or "outer" bound on the time when the present Bay bottom was sub-aerially exposed in the vicinity (ie. as an island). This can be considered an outer bound by the following reasoning. Consider, for example, the erosion of the present Poplar Island group. The remnant islands stand some 2-3 feet above sea level, and the erosion over the past 100 or so years has been well documented. Water depths in the immediate vicinity of the present islands and within the 100 year erosion envelope are in the 6 to 10 foot depth range. Clearly, as erosion occurs, sediments are removed to some depth below the existing sea level. The depth of this erosion probably represents the depth of the active "wave base." It is likely, therefore, that an island existed at the shoal in Area 1 for some significant period of time after sea level had reached the 10 foot minimum depth of the present

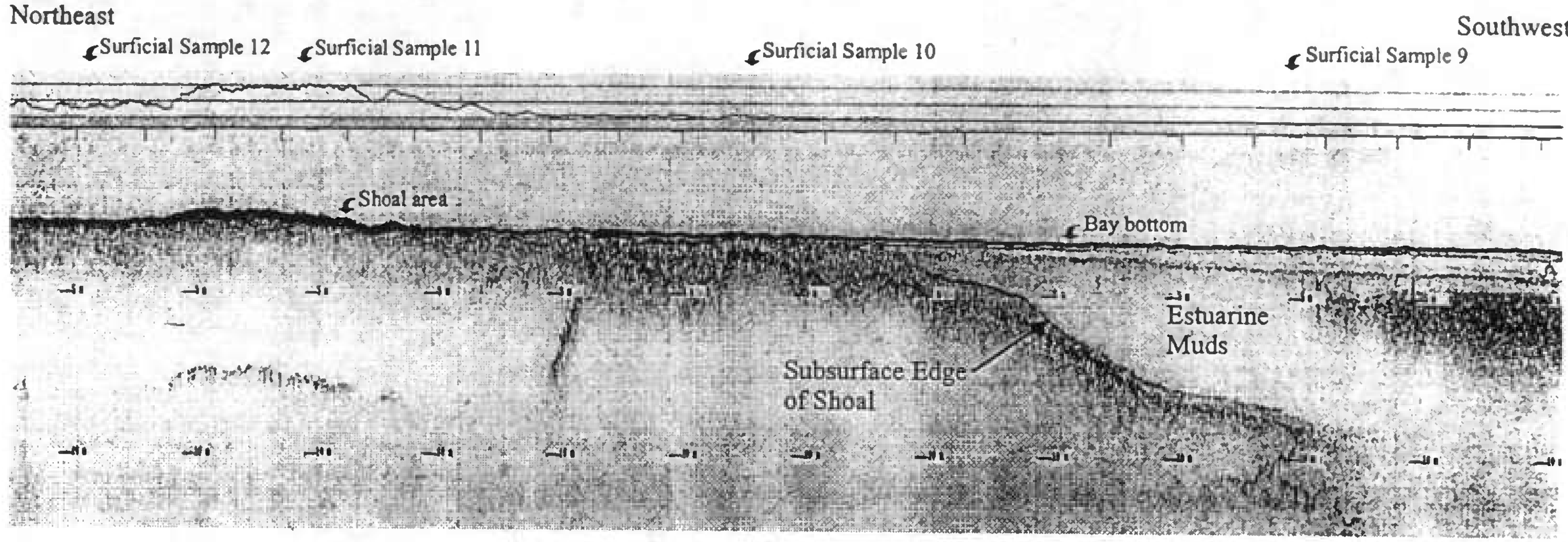

Figure 6: Sub-bottom image along Line 4 in Area 1, in the vicinity of surficial sediment samples 9 - 12. Note the steep dip of the shoal edge beneath finer grained estuarine muds on the right side of the image. Surficial sediment grain sizes in Table I indicate a change from predominantly sand sized particles on top of the shoal (Samples 11 and 12) to all silts and clays in the estuarine muds (Sample 9).

shoal (2,000 years ago). However, the time frame for the existence of this island is speculative and would depend on factors such as wind patterns, climate in general, including temperature and rainfall, and the relative erodibility of the sediments comprising the island. Thus, while an island probably has not existed in the location in the past 400 years, one certainly existed 2,000 years ago, and likely was slowly eroded during the period prior to European exploration and mapping of the Chesapeake.

Area 2

Area 2 is located immediately northwest of the intersection of the Brewerton Channel Eastern Extension and the Tolchester Channel (Figure 7). Water depths in the area are generally in excess of 20 feet. A discontinued dredged sediment placement area is located parallel to, and just north of, the Brewerton Channel Eastern Extension.

No sediment samples were collected within the limits of Area 2, but the side-scan and sub-bottom records indicate that the bottom consists of fine grained estuarine muds. Surficial grab samples collected by the Maryland Geological Survey in the mid-1980's in the area consisted entirely of fine grained muddy sediments (Kerhin et al., 1988). In those samples, sand sized particles composed less than 1% of the sediment while the finest clay sized particles comprised between 55 and 60% with the remainder consisting of silt sizes. Organic carbon contents ranged from 2 to 3 percent.

Although no side-scan records within the bounds of Area 2 are reproduced, the entirety of the area appeared similar to that shown in Figure 8, which was recorded at surficial sediment station 3 located just north of the area. Sediments at this station consisted of fine grained organic rich muds with a low amount of sand sized particles. Complete grain size analysis was not conducted for this sample. The remainder of the side-scan records showed that the muddy sediments at station 3 and in all of Area 2 were smooth and flat with occasional pock marks and faint, narrow, randomly oriented lineations. The origin of these features is uncertain but they probably represent anchor drag marks, shell fish dredging scars, or activities of a similar nature. There is a faint appearance of some very low relief mud waves on the bottom in Figure 8, but these are interpreted to be the result of interference from surface water waves at the time the record was collected.

The sub-bottom records from Area 2 showed internal reflectors that were weak, discontinuous and parallel to sub-parallel to the sediment water interface. All these properties are characteristic of fine grained organic rich sediments accumulating in the estuary. Methane filled gas voids were commonly present in these muddy sediments and generally occurred at depths between 6 and 10 feet below the sediment water interface. These voids are a common feature of fine-grained organic rich muddy sediments in estuarine environments. Within the section identified as the discontinued dredged sediment placement area, small pockets of strong acoustic reflection were present higher in the sediment column. These were interpreted to represent locations where larger amounts of methane gas are located closer to the sediment water interface. Whether or not these are the result of, or influenced by, the use of this area for dredged sediment placement in the past, is unknown.

Fine grained sediments that accumulate in relatively deeper waters of the Chesapeake Bay commonly have a rapid sedimentation rate and a high labile organic matter content. These factors result in the generation of methane gas by bacterial decomposition of the organic matter. The gas generation rate is high enough to exceed the solubility of methane in sea water and free methane filled gas voids form within the sediments (Hill et al., 1992). The transition from a water/sediment mix to gas filled void has a very high velocity density contrast and results in the

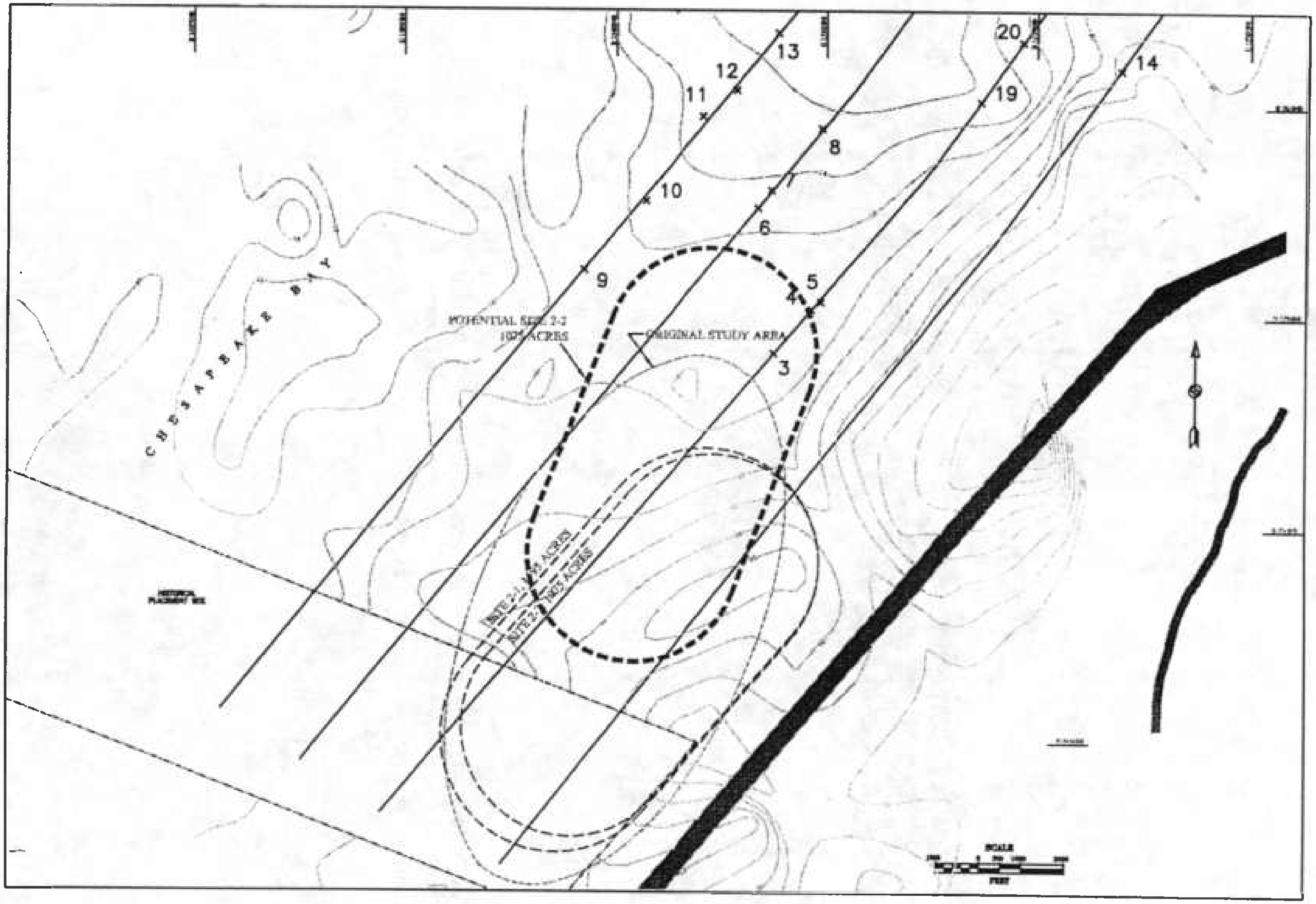

Figure 7: Study Area No. 2 with acoustic tracklines and sediment sampling sites.

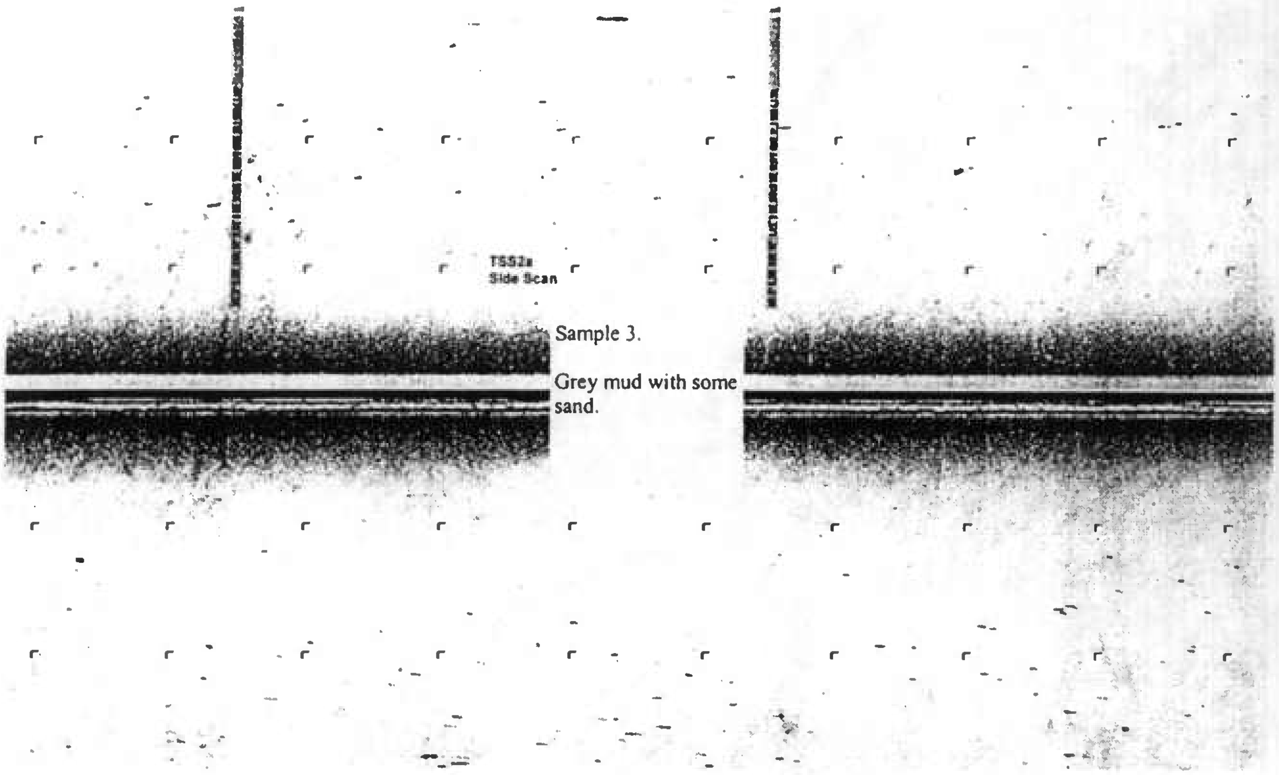

Figure 8: Side-scan sonar image of the smooth featureless muds at the location of surficial sediment station 3, northeast of Area 2. Full grain size analysis was not conducted on this sample, however, the field description indicated that the sediments were nearly entirely muds.

reflection of most of the incident acoustic energy back to the sub-bottom survey equipment (Halka and Gardner, 1987; Trabant, 1984). The strong reflection also prevents further penetration of acoustic energy into the sediments below the gas zone and precludes the possibility of interpreting other sediment layers that may be present in the sediments. However, previous work conducted by the Maryland Geological Survey indicates that methane gas filled voids generally only form in those areas where the thickness of fine grained Holocene sediments exceeds 10 meters (Colman and Halka, 1990a, 1990b; Colman et al., 1990; Halka et al, 1996). Thus, it can be assumed that the soft fine grained sediments present at Area 2 are at least 30 feet thick across the entire area.

Although the borings collected by E2Si showed the presence of sand in the subsurface in the northwest portion of Area 2, there was no evidence of this sand layer in the acoustic records. The fine grained organic rich sediments are thick enough and the rate of methane gas generation fast enough in these sediments to prevent the penetration of the acoustic signal below the gas filled voids in the sediments.

Area 3

Area 3, located just to the west of the dredged Swan Point Channel, has water depths in the 20 to 30 foot range, although toward the eastern portion of the area, in the vicinity of the shipping channel, depths increase to over 30 feet (Figure 9). In this area the bottom slopes toward the channel. Four tracklines were run across the area and grab samples collected at two sites.

Both the side-scan and sub-bottom records were monotonously uniform across the entire area. The side-scan records showed a generally smooth and flat bottom with low acoustic backscatter, characteristics indicating fine grained sediment accumulation in the absence of strong currents. A representative example collected at sediment sampling station 1 is shown in Figure 10. Occasional linear features were noted on the side-scan records. These were attributed to anthropogenic activities such as anchoring, shellfish dredging, pipelines or cables. There is generally no preferred orientation to these features, nor is there any grouping to the distribution across the area.

Sub-bottom records throughout Area 3 showed a generally low intensity first bottom return with very faint, sub-parallel internal reflectors or acoustically transparent sediments in the upper 5 to 6 feet of sediment (Figure 11). At this depth a diffuse but fairly strong return is encountered which attenuates further signal penetration. As stated previously, this return signal is characteristic of the presence of methane gas bubbles in the interstitial pores of the sediment.

Sample 1, located at the western edge of the area, returned sediment consisting almost entirely of mud with less than 1% sand sized particles. Clay sized particles made up approximately 60% of the sediments and silt particles the remaining 40% (Table I). Surficial grab samples collected by the Maryland Geological Survey in the mid-1980's in the area consisted entirely of fine grained muddy sediments (Kerhin et al., 1988). Sand sized particles composed less than 1% of the sediment, clay sized particles between 56 and 69%, and the remainder silt sizes. Organic carbon contents ranged from 3.2 to 3.9 percent.

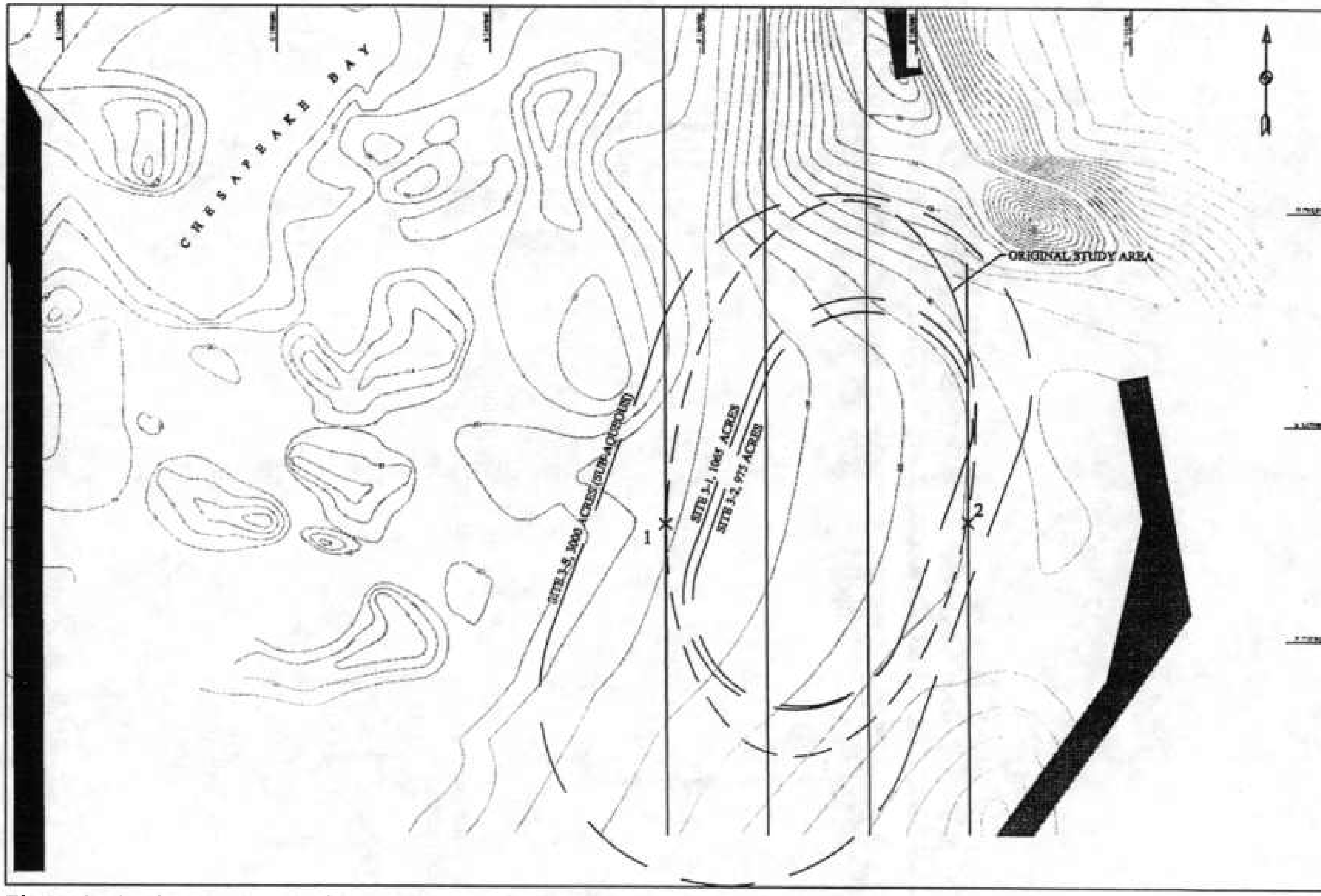

Figure 9: Study Area No. 3 with acoustic tracklines and sediment sampling sites.

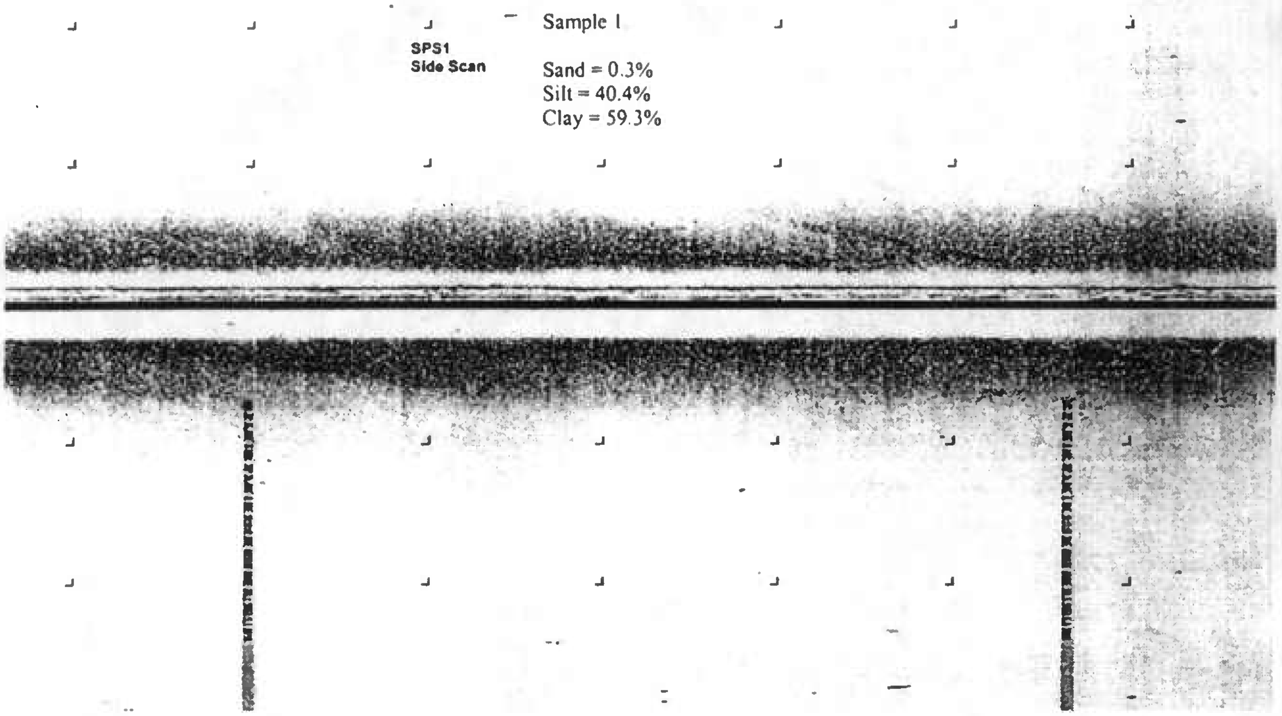

Figure 10: Side-scan sonar image taken in Area 3, in the vicinity of surficial sediment sample number 1. Note the smooth, nearly featureless character of the bottom with little variation in acoustic backscatter.

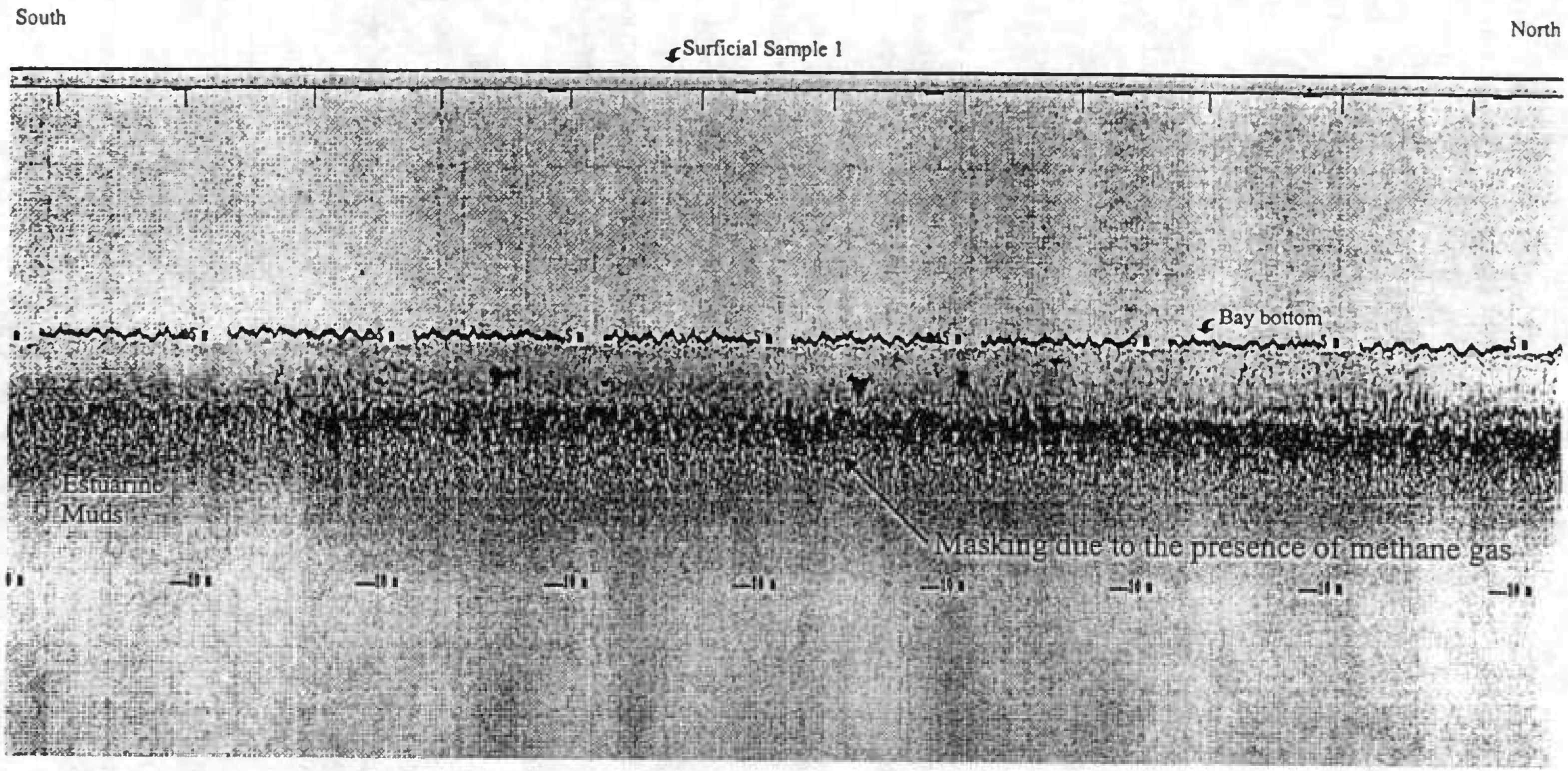

Figure11: Sub-bottom image along Line 4 in Area 3, in the vicinity of surficial sediment sample 1. Methane filled gas voids in the sediments prevent penetration of the acoustic signal beyond about 2 meters below the bay bottom. Pockets of methane gas are occasionally present at shallower depths in the sediment.

Area 4A

Area 4A, located east and northeast of Pooles Island generally encompasses a number of areas which have been previously designated for open-water placement of dredged sediments (Figure 12). This has resulted in the placement of significant thicknesses of fine-grained mud removed primarily from the approach channel to the C&D Canal, as well as some from the Brewerton Channel Eastern Extension and the Tolchester Channel. The presently designated placement areas G-North, G-Central and G-West lie within the boundary of Area 4A. In addition, Area G-East, proposed for placement of sediment is located in the central portion of Area 4A.

Early bathymetric maps show a trough like feature extending from the northern end of Area 4B in a south-southwest direction parallel to Pooles Island. Within this trough depths ranged from 30 to over 60 feet in 1938. This area was first utilized for the placement of dredged sediments when the C&D Canal approach channel was deepened to 35 feet in the 1964-1968 period. The following assessment of dredged sediment thicknesses in each of the areas is based on data collected and available at the offices of the Maryland Geological Survey.

Bathymetric changes between 1938 and the present indicate that between 35 and 50 feet of sediment has been placed in the trough just to the north of Area 4-A. Water depths in 1938 were in excess of 45 feet in the area and presently are in the 12 to 14 foot range. Areas G-North and G-Central have had between 20 and 35 feet of sediment placed as a result of dredging activities. Placement of sediments within these areas was historically accomplished primarily by hydraulic pipeline discharge. In the more recent past bottom release scows created mound like features on these placement areas. The hydraulic placement technique resulted in the significant spread of sediments outwards from the designated areas. Much of this sediment spread into Area G-West and the proposed G-East placement area. Since 1993 placement has occurred directly in G-West. The combination of historical placement in G-North and G-Central and the more recent placement directly in G-West has resulted in the accumulation of a 10 to 20 foot thickness of dredged sediments in this location.

Six acoustic sub-bottom tracklines were surveyed across the proposed G-East placement area in August 1996 (Figure 12). No side-scan records have been obtained in this area. The following interpretation of these data can be anticipated to generally apply to the majority of Area 4A. Strong acoustic returns from at, or just below, the sediment water interface were characteristic of those portions of the tracklines that crossed Areas G-Central and G-North. This type of return was also present between 0.5 and 1.0 kilometer east of these placement areas, in the proposed G-East location. This type of return is characteristic of methane gas filled voids present near the sediment water interface, as described above. The placement of organic rich dredged sediments in these areas has lead to the production of methane gas which attenuates penetration of the acoustic signal and prevents interpretation of the sediment characteristics below the zone of methane. However, the bathymetric comparisons outlined above indicate that there is a significant accumulation of dredged sediments in these areas. In the western portion of the proposed G-East area, approximately 8 to 10 feet of dredged sediment accumulated between 1938 and the mid-1990's, contributing to the production of methane gas in this area. The eastern

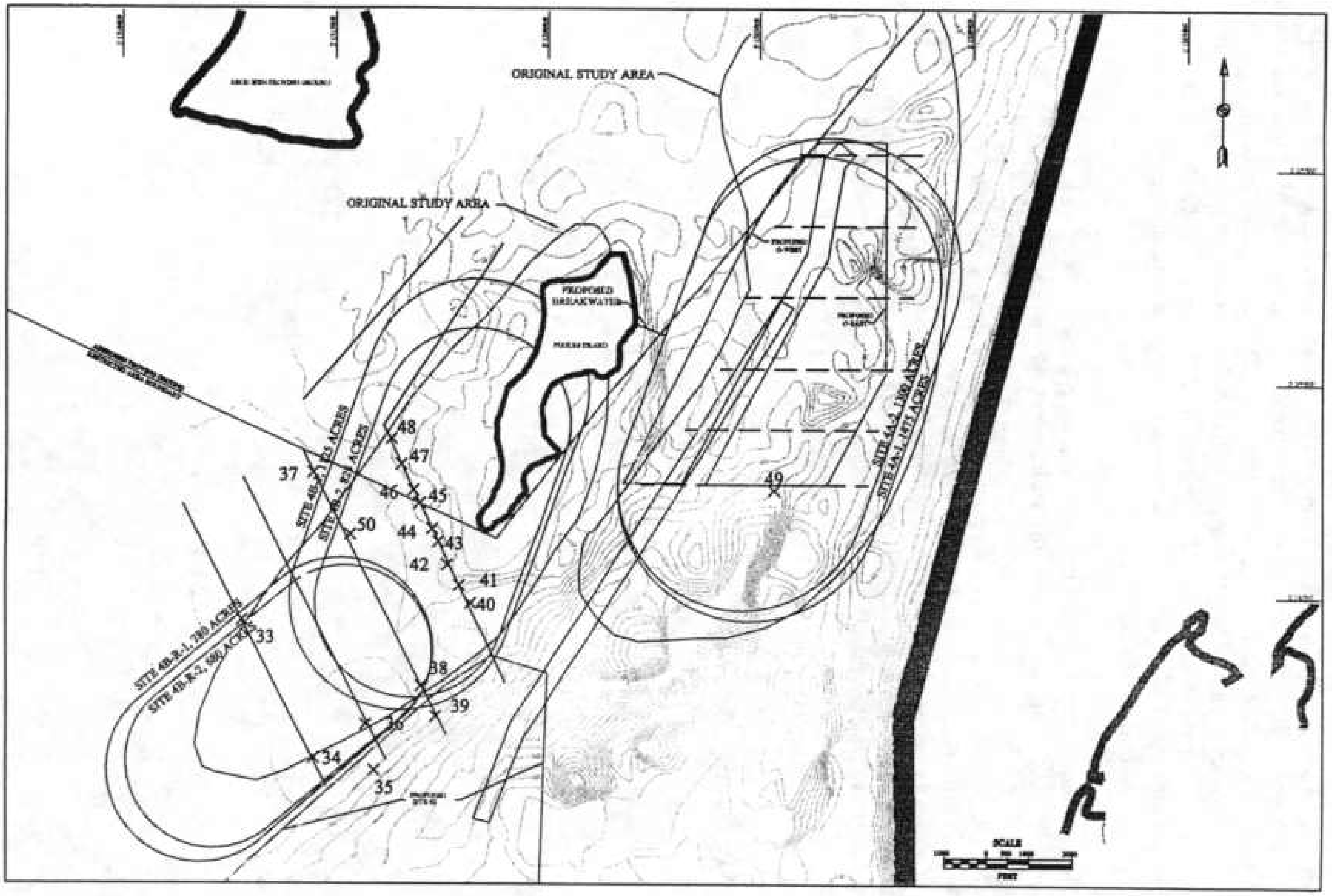

Figure 12: Study Area No. 4 with acoustic tracklines and sediment sampling sites. Solid tracklines run with Edgetech Chirp System, dashed tracklines run with Datasonics System.

portion of G-East, in contrast, showed some penetration of the sub-bottom signal. The records were similar to those described in Areas 2 and 3 above. Weak, discontinuous sub-parallel reflectors were present in the shallow sub-surface above a zone of methane gas that was located approximately 6 feet below the sediment water interface. This provides an indication that natural sedimentation has occurred in this area and accumulated fine-grained sediments to a significant thickness. It is anticipated that much of the northern half of Area 4A, that has not been directly affected by the placement of dredged sediments, would show sub-bottom sediment characteristics of a similar nature.

The northernmost portion and the southernmost portion of Area 4A has a bottom with highly variable relief. The area in the north has been extensively excavated for fossil oyster shell in the past 5 years. The remaining shallow portions that have not been excavated consist primarily of relatively compacted muds with admixed oyster shells forming a firm bottom type. Similar bottom sediments occur in the south end of Area 4A in an area with high relief that has been characterized as a prime fisheries habitat zone. The shallow zones in this area consist of firm compacted clays and oyster shells. Some of the deeper waters contain soft muddy sediments but some are also characterized by compacted clays. Sampling station 49, located in one of these deep areas (Figure 12) returned a firm solid clay sediment, although grain size analysis was not conducted.

Area 4B

The portion of Area 4B located to the south of Pooles Island was surveyed using the Chirp acoustic equipment and samples were collected for ground truth. Two acoustic lines were also run to the west of Pooles Island, however, no ground truth samples were collected in this area. Water depths were variable in this survey area, ranging from less than 8 feet proximal to Pooles Island and on the shoal extending to the SSW, to 12 to 14 feet further south of the island.

The two lines furthest to the southwest of Pooles Island were similar in nature. The side-scan records showed a bottom that was smooth and flat with little variation in signal strength. Portions of the lines showed linear scars on the bottom that were undoubtedly the result of anthropogenic activities. The sub-bottom records for these lines were also similar and showed a bottom that consisted primarily of acoustically transparent sediments with a notable gas horizon present approximately 6 to 7 feet below the sediment water interface. Figure 13 shows an example of the sub-bottom record collected along the line furthest southwest of Pooles Island. Across most of the left side of the figure, the record is obscured by the presence of methane gas approximately 2 meters below the bottom. As noted previously this type of sub-bottom record commonly occurs where the fine grained organic rich sediments are at least 30 feet thick. Surficial sediment sample 33, collected in this area, consisted almost entirely of fine grained sediments with less than 2% sand. Toward the right side of Figure 13, the water gradually shoals and the return from the methane gas voids gradually decreases in strength until it is finally replaced by an acoustic multiple of the bottom. This area is the southward end of the shoal extending to the southeast from Pooles Island. The sediment characteristics at station 34 were similar to those at station 33, consisting primarily of fine grained muds. Apparently the thickness of the muddy sediments is somewhat less in this part of the line resulting the lower generation rates of the methane gas in the sediments.

Located closer to Pooles Island, the sub-bottom record along Figure 14 shows essentially the same characteristics across most of its length. The northwestern portion of the line crosses sediments that have relatively transparent sub-bottom characteristics with methane gas apparent locally in the sub-surface (Figure 14, left side). The methane gas in the record is, however, discontinuous and shows weaker characteristics than in the two lines located further to the southwest. These characteristics suggest that the fine grained sediments are less thick in this portion of Area 4B and that the critical sediment thickness for the generation of gas has not been reached. Below sampling station 50 a faint sub-bottom horizon appears approximately 7 meters below the sediment water interface with no gas present above. The record is too faint and discontinuous to be certain of the identification, but this may represent firmer sandy sediments below the fine grained muds in this area, and provides an indication that the muddy sediments are approximately 20 feet thick.

Toward the eastern (right) side of this line a notable reflector appears in the subsurface and rises to become a shallow platform (Figure 14). This platform is the shoal that extends to the south of Pooles Island and on which the Pooles Island Light is located (Figure 12). This platform has a very strong first return signal on the sub-bottom record indicative of a firm bottom type. The side-scan record from the vicinity of sampling station 38 shows numerous apparent

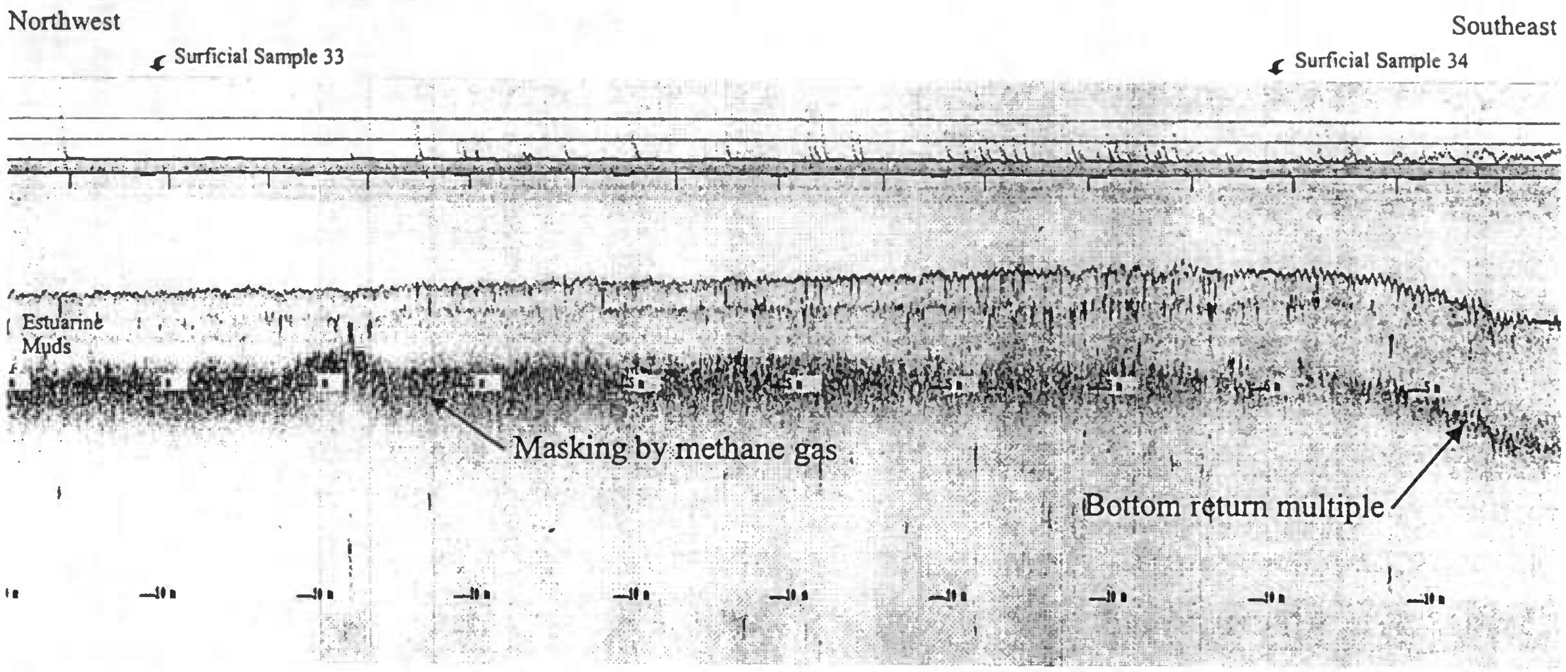

Figure 13: Sub-bottom image in Area 4-B, southwest of Pooles Island. Surficial sediment samples 33 and 34 are located along this line. Faint sub-horizontal internal reflectors are present along most of this line in the upper meter of sediment. Methane bubbles obscure the record approximately 2 meters below the sediment surface on the left side of the figure. The methane becomes less prevalent to the right and gradually merges with a bottom multiple.

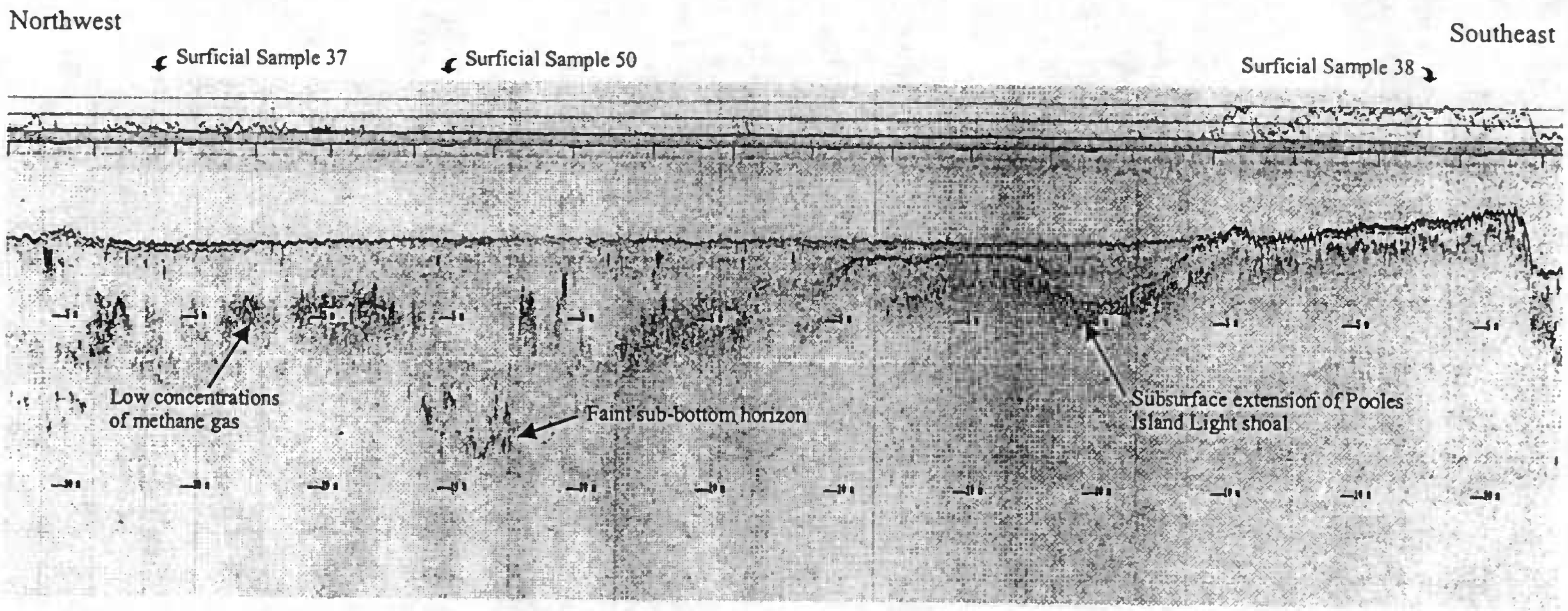

Figure 14: Sub-bottom image in Area 4-B, southwest of Pooles Island. Surficial sediment samples 37, 50 and 38 are located along this line. Low amounts of methane obscures portions of the record on the left side of the figure, with a faint sub-bottom horizon apparent below sample 50. On the right side the sub-bottom extension of the Pooles Island Light shoal rises to the surface.

wave forms on the bottom oriented approximately east to west (Figure 15). The steep sides of these waves face toward the north indicative of transport in that direction. The grab sample at station 38 returned only disarticulated oyster shells. It may be the case that the oyster shells are being actively moved by wave activity in the area.

The closest line run to Pooles Island showed quite a bit of variability in both water depth and acoustic characteristics. Samples 40 through 48 were collected along this line to provide ground truth data (Figure 12). The sub-bottom record (Figure 16) shows the variation in both the depth and subsurface characteristics along the line.

The deeper areas along this line exhibit lower signal strength at the sediment water interface and some subsurface penetration (Figure 16). Where signal penetration occurs the subsurface sediments are either acoustically transparent or exhibit a variety of shallow internal reflectors. These characteristics indicate that a variety of sediment types that are primarily fine grained have accumulated in the slightly deeper waters. The grab samples confirmed these interpretations. Station 41 was primarily sandy but contained nearly 30% mud, station 42 was approximately half sand and half mud, while station 47 was primarily mud with about 25% sand sized materials.

The sub-bottom record exhibited strong surface return signals in the shallow waters indicative of relatively hard bottom types (Figure 16), and the surficial sediment samples again confirmed this interpretation (Table I). At station 40, located at the northern end of the Pooles Island Light shoal, the sampler returned all oyster shells and no sediment could be collected for grain size analysis. Stations 43 and 44, located on a platform in the approximate center of the line consisted of mostly sand sized particles with a 20% admixture of muds. Station 48 located at the northwestern side of the line was nearly all sand sized particles. Samples 45 and 46 were collected on the shallower relatively flat platform just to the northwest of samples 43 and 44. The side-scan record in this area was unique among those collected in this project. The bottom had a number of small distinct strong reflectors giving the whole record a "specular" return pattern (Figure 17). The sampler returned only mixtures of cobbles from these stations, some as large as 10 inches across. This was a unique bottom type and the side-scan record suggests that the cobbles extend at least to the edge of the record, 75 meters from the trackline center. Whether or not the cobbles extend further to the southwest is unknown without collecting additional survey line data. However, this bottom signal type did not appear on the next survey line to the southwest so the cobbles do not extend that far from Pooles Island (Figure 12).

No samples were collected along the survey lines run to the northwest of Pooles Island because of their location within the boundary of Aberdeen Proving Ground. Acoustic records were collected but are not reproduced here. These two lines essentially duplicated the range of conditions encountered to the southwest of Pooles Island. In relatively shallow water adjacent to the island the sediment surface returned a strong signal and some sub-bottom penetration was achieved, indicating that these sediments were primarily sandy materials. In certain areas the side-scan records gave evidence of sand waves on the bottom and some "specular" returns were encountered suggesting additional areas with cobbles on the bottom. In slightly deeper waters west of Pooles Island the bottom sediments appeared to be soft fine grained muds with methane

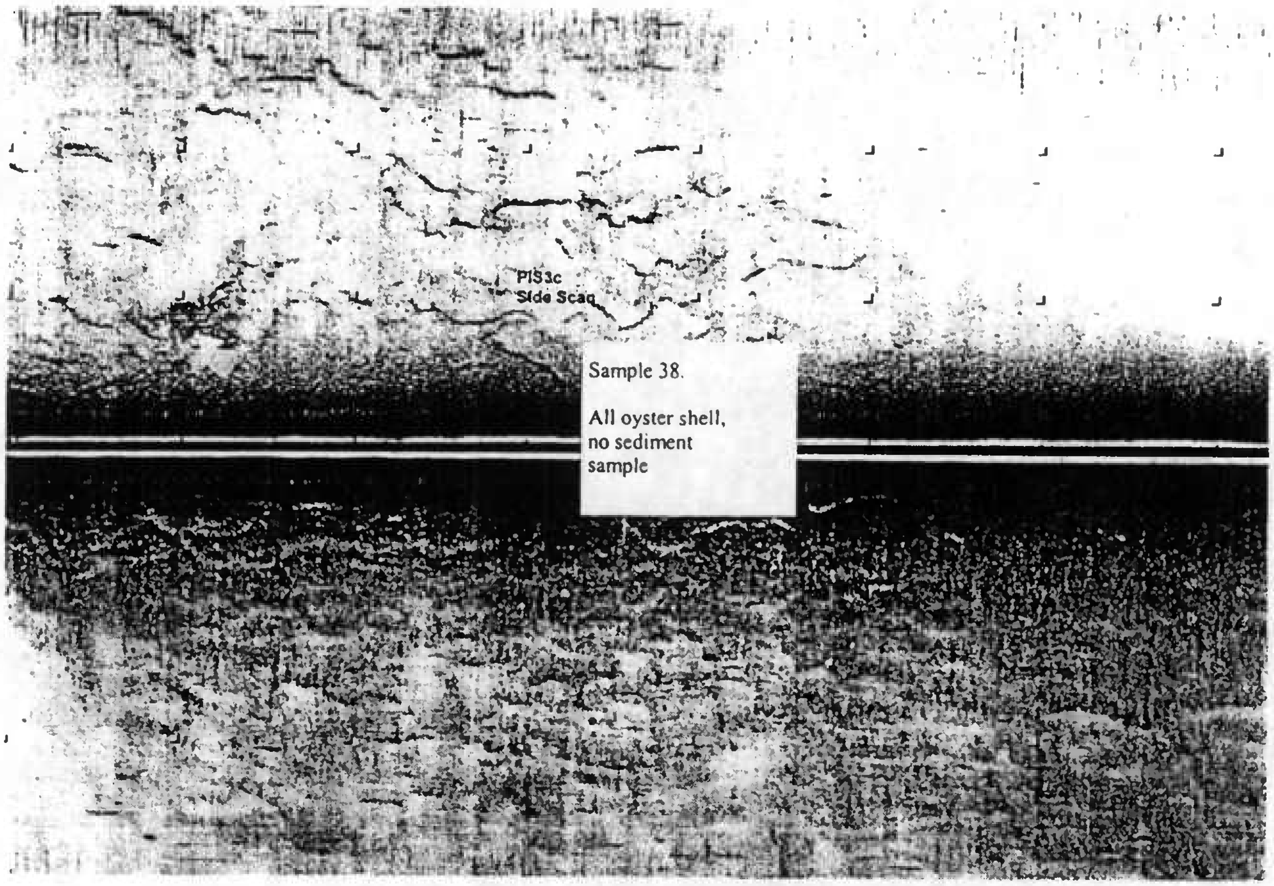

Figure 15: Side-scan sonar image taken in Area 4B, on top of the Pooles Island Light shoal. The sinuous features oriented approximately horizontally across the figure are interpreted as wave forms on the bottom. The steep faces are directed to the north. Surficial sample 38 returned all disarticulated oyster shells.

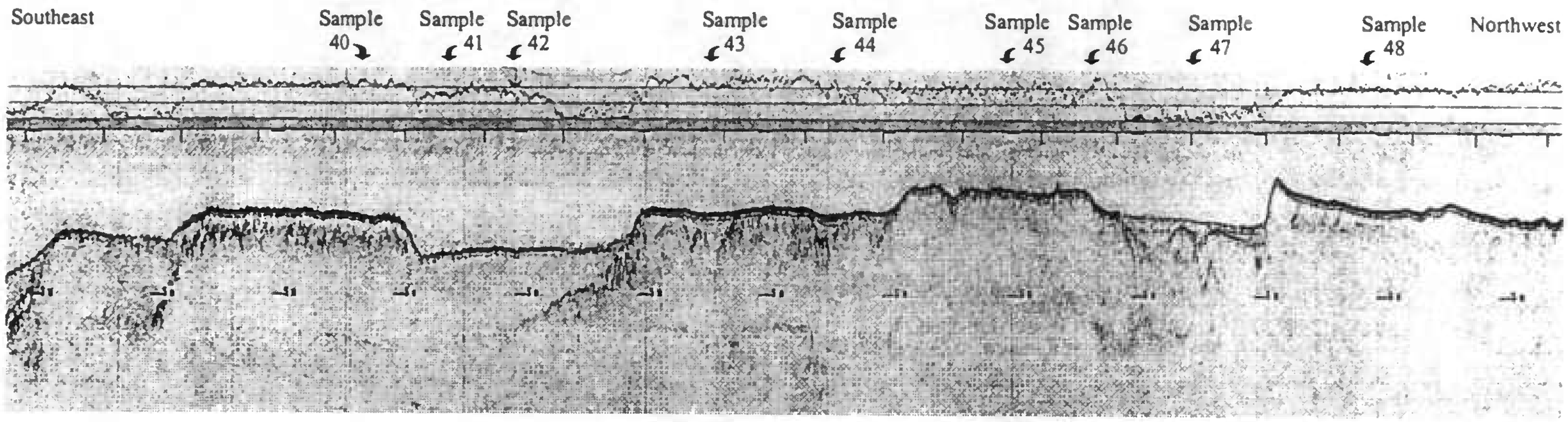

Figure 16: Sub-bottom image in Area 4-B, closest to Pooles Island. Surficial sediment samples 40 - 48 were located along this line. Note the variations in water depth and sub-bottom reflection characteristics along the length of the line. Relatively shallower waters have strong surface returns (darker lines) and little or no sub-bottom penetration. Slightly deeper waters generally show lower signal strengths at the sediment water interface and some sub-bottom penetration. Surficial sediment characteristics varied considerably (see Table I).

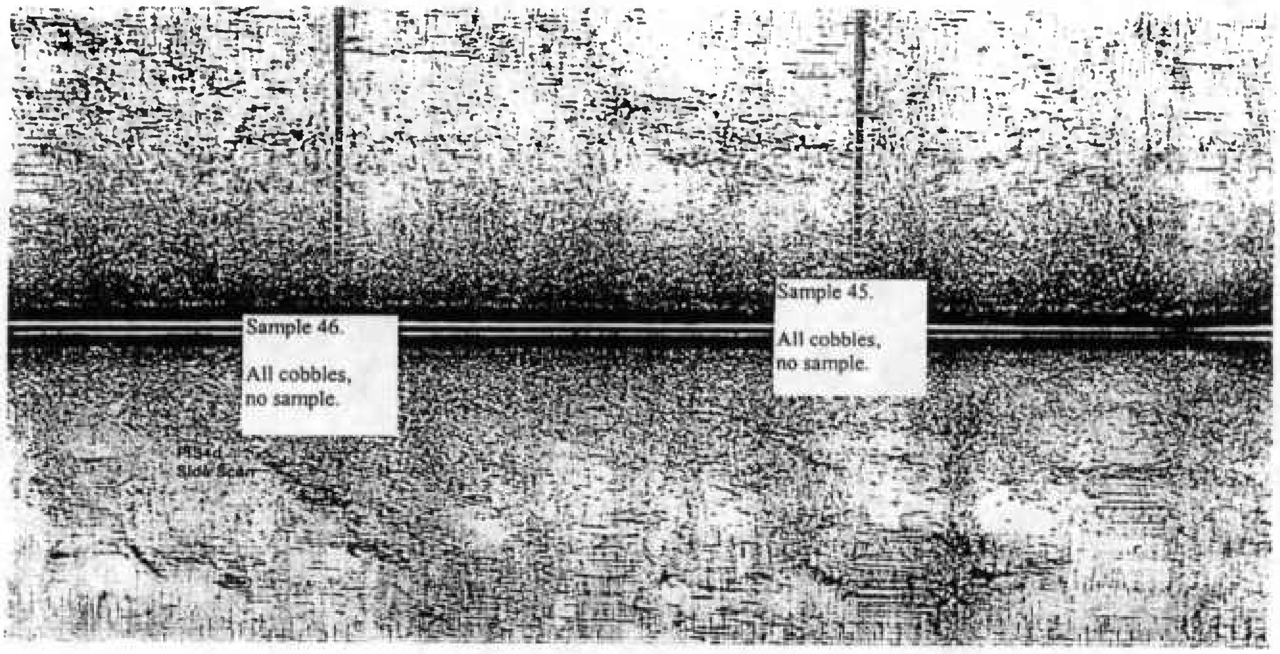

Figure 17: Side-scan sonar image taken in Area 4B, immediately southwest of Pooles Island. Note particularly the "specular" pattern of reflectors on the bottom. The cobbles returned in both sample 45 and 46 suggest that each of these reflective points represents a cobble on the bottom.

gas attenuating the signals 6 to 8 feet below the surface. The line closest to Pooles Island also contained numerous shallow roughly circular depressions that may have been produced by artillery activities conducted in the area.

Table I: Proposed Island Site surficial sediment samples

Sample I.D.	MD State Plane(ft): North	East	Percent H20	Bulk Density	Grain Size Analysis: Sand %	Silt %	Clay %
1	522678.4	1499162.9	69.8	1.23	0.32	40.4	59.28
2	522730.5	1506257.6	72.92	1.2	Soft medium grey mud		
3	554133.7	1508762.6	59.81	1.33	Somewhat firm medium grey mud		
4	555172.5	1509652.3	59.72	1.33	3.44	57.1	39.46
5	555356.4	1509887.1	61.37	1.32	Soft medium grey mud, numerous shells		
6	557591	1508382.1	57.32	1.36	2.52	51.65	45.83
7	558018.4	1508700.1	57.6	1.36	4.68	37.28	58.05
8	559484.5	1509902.8	40.27	1.62	68.59	17.07	14.22
9	556103.2	1504259.9	59.65	1.33	1.32	50.84	47.85
10	557753.1	1505712	64.14	1.28	7.56	49.23	43.09
11	559766.5	1507066.7	29.32	1.78	80.63	10.59	8.78
12	560379.6	1507865	46.14	1.5	35.99	33.62	30.39
13	561722.6	1508846.7	21.38	1.96	95.34	2.63	2.03
14	560875	1516976.8	59.54	1.34	Soft medium grey mud		
15	564170.9	1519217.6	56.52	1.37	4.58	43.86	51.56
16	564989.3	1519824.9	64.51	1.28	Soft medium grey mud, numerous shells		
17	568750.7	1522533.3	59.11	1.34	Soft medium grey mud, some shells		
18	574185.3	1526407.3	56.42	1.37	Soft medium grey mud, few shells		
19	560120.6	1513676.5	22.67	1.93	92.59	2.94	4.47
20	561524.5	1514657.4	No sample all oyster shells				
21	568544.9	1519607.5	58.95	1.34	7.92	44.73	47.35
22	574162	1523575.1	49.17	1.46	12.24	40.59	47.17
23	563087.3	1512661.7	26.36	1.82	95.59	2.14	2.24
25	567115.4	1515416.5	No sample all oyster shells				
26	567605.3	1515955.6	38.11	1.59	Soft medium grey mud with shell hash		
27	569864.5	1517613.9	59.76	1.33	14.22	54.27	31.51
28	571635.5	1518921.8	55.86	1.38	11.1	49.41	39.49
29	573467.1	1520229	58.08	1.35	13.97	50.45	35.58
30	564225.4	1510669.4	20.45	1.94	96.33	2.21	1.46
31	569903.3	1514827.9	56.91	1.37	8.08	55.23	36.69
32	574057.5	1518147.1	54.67	1.39	11.8	52.78	35.41
33	584396.6	1512826.9	65.02	1.28	1.51	53.12	45.37
34	581131.5	1514504.1	66.33	1.27	1.7	46.82	51.48
35	580839.1	1515922.2	59.15	1.34	Soft medium grey mud, few shells		
36	581930.2	1515724.8	60.74	1.32	4.45	60.43	35.13
37	587869.9	1514498.6	60.95	1.32	14.17	44.99	40.85
38	582851.2	1517038.9	No sample all oyster shells				
39	582125.4	1517375	61.14	1.32	Soft medium grey mud, few shells		
40	584803.1	1518203.2	No sample many oyster shells with some pebbles				
41	585225.9	1517940.3	32.47	1.72	71.29	10.23	18.47
42	585709.3	1517653.3	50.38	1.45	55.59	16.57	27.84
43	586253.9	1517436.6	31.21	1.75	80.31	6.26	11.65
44	586556.3	1517292.7	28.17	1.81	Grey sand and mud		
45	587161.1	1517004.8	No sample all cobbles				
46	587463.5	1516860.9	No sample all cobbles				
47	588068.3	1516572.9	56.93	1.36	24.65	44.3	31.05
48	588673.5	1516332.3	20.45	1.98	96.93	1.14	1.54
49	587471.4	1525353.7	46.61	1.48	Solid medium grey mud		
50	586419.7	1515359.2	50.68	1.44	Soft medium grey mud, few shells		

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APPENDIX C
GLOSSARY

GLOSSARY

abundance	number of organisms per unit area
acid volatile sulfides (AVS)	used as a measurement to determine the bioavailability of trace metals
acoustic data	obtain a bottom profile of sediment characteristics obtained with a low-frequency soundwave
aesthetics	values derived from beauty or good taste rather than usefulness
alongshore	parallel to and near the shoreline (longshore)
amphibians	cold-blooded, smooth-skinned, vertebrate organisms that hatch as aquatic larvae and breathe using gills and metamorphose into adult forms with air breathing lungs (i.e., frogs)
anadromous	fish that migrate from the ocean to breed in freshwater; requiring freshwater to breed or spawn
annual costs	cost of site dewatering and management, operation and maintenance (o&m), crust management, and site monitoring for the life of the site
anoxic	lacking oxygen
anthropogenic	derived from human origin (i.e., impacts that originate from human activity)
APG	U.S. Army's Aberdeen Proving Ground
archaeological	material evidence remaining from past human existence and culture
armor unit	large quarrystone or concrete shape that is used for wave protection structures
armor	layer of rock providing erosion protection

astronomical tide	the periodic rising and falling of the water that results from the gravitational attraction of the moon and sun and other astronomical bodies acting upon the rotating earth
Atterberg Limit	water content ranges of the soil denoting behavior in the solid, liquid and plastic stages
bathymetry	the measurement of depths of water in oceans, seas, bays and lakes
beneficial use	placement or use of dredged material for some productive use (i.e., island restoration, shoreline stabilization)
benthic macroinvertebrate	aquatic invertebrates smaller than 0.5 mm (includes worms, crustaceans, bivalves) that live on or within sediments
benthic	living at the sediment-water interface at the bottom of a water basin
berm	horizontal ledge on the side of an embankment to add strength to the structure or to restrict material loss
bioavailability	the amount of a toxic substance/material that is available for uptake by an organism; varies depending on chemical and physical characteristics of the toxic substance and with characteristics of the sediment and organism
biological considerations	potential impacts of island construction on benthos, fish, and other sensitive species; considerations included total abundance, species diversity, relative productivity, and the aerial extent of submerged aquatic vegetation (SAV); Island footprints were selected to minimize potential biological impacts
biomass	weight of living material, usually expressed as dry weight or ash-free dry weight per unit area
biota	life in any form; fauna and flora of a given region

borrow material	soil or sediment taken from a site for use as construction material (i.e., sandy sediment dredged and pumped to restore an eroded beach, or clay used to build a levee or dike
brackish	water with a salinity of 0.5 ppt to 30 ppt
breaker	a wave breaking on a shore, over a reef, etc.
breakwater	a structure protecting a shore area, harbor, anchorage, or basin from waves
cap	a layer of clean material that provides environmental isolation
carnivore	organism that feeds on animal tissue
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980; also known as "superfund"
charter boat	a boat that provides daily trips for a fee, usually licensed to carry a maximum of 6 people
chlorophyll	photosynthetic pigment in plants; provides a measure of phytoplankton densities
clay	sediment grain size less than 2 microns in diameter and often colloidal in nature
coast	a strip of land of indefinite width that extends from the shoreline inland to the first major change in terrain features
coastal data	wind directions, wave characteristics, current velocity and direction, and tidal range
coastline	line separating the coast and the shore, or, more commonly, the boundary between land and water
cobble	rock fragments intermediate in size between a pebble and a boulder with a diameter >64 mm and <256 mm
cone penetrometer probings	a conical-shaped probe used to measure the penetrability of semisolids

containment facility	an engineered structure for containment of dredged material consisting of dikes or other structures that enclose a disposal area above any adjacent water surface, isolating the dredged material from adjacent waters during placement
culch	a natural bed for oysters that consists of crushed shells or gravel to which oyster spawn may settle and adhere
cultural resources	elements of the human social environment to which a value is attached (i.e., historical sites or structures, recreational activities and areas, aesthetics)
current	a flow of water, typically generated by wave action, tidal fluctuations, or winds
deep water	water deep enough that waves are not affected by the bay bottom
depth	the vertical distance from a specified tidal datum to the sea floor
digitize	to convert something such as a map into digital form
dike	an embankment constructed (typically using soil and rock) to contain dredged material or to serve as a protective barrier
dike-raising costs	costs of incremental raising of the dikes using dried dredged material crust, based on geotechnical considerations
dike footprint	maximum profile width of the dike
dissolved oxygen	oxygen molecules dissolved in water that are necessary for the respiration of aquatic organisms
diurnal tide	having a period or cycle of approximately one tidal day
diversity	a measure of the variety or number of different types of organisms present in a community or given location; the number of distinct species in a community or ecosystem

dredged material	material dredged from ocean or coastal waters
dredging/transport and placement costs	costs for dredging the navigation, channels, transport to the placement site, and unloading of the dredged material at the site for the design life of the site
effluent	liquid or material that is discharged from an outfall
emergent species	herbaceous non-woody plants standing erect; appearing above the water surface
environmental considerations	potential impacts on water quality, presence of contaminants at the site, and previously impacted areas (historical dredged material or industrial waste discharge areas); Site layouts were selected to have minimal impacts to the biota and fisheries/oyster resources and minimal potential resuspension of sediment-bound contaminants into the water column
environmental data	a variety of field data (benthic macroinvertebrates, in-situ water quality, and sediment quality/grainsize) within each of the five proposed sites; existing information on fisheries habitat (and fish havens) and oyster bar locations; SAV, wetland and upland habitat distributions at each of the proposed sites
estuary	a partially or semi-enclosed body of water where freshwater and seawater meet and mix
eutrophication	nutrient enrichment in a body of water
extratropical storm	storms commonly referred to as northeasters that develop in the mid-latitudes in response to the interaction of warm and cool air masses
factor of safety	ratio of resisting force to driving force causing instability of a slope
fauna	animals as a group especially animals specific to a region

fetch	the area in which seas are generated by wind having a fairly constant direction and speed; the horizontal distance (in the direction of the wind) over which a wind generated seas
fish haven	areas where foreign materials or structures such as old concrete or steel structures have been deposited to create artificial reefs and enhance fish habitat
flora	plants, especially plants specific to a region
foreshore	the part of the shore lying between the crest of the seaward berm and the ordinary low-water mark
formalin	a diluted solution of formaldehyde used to preserve biological specimens for later examination
freshwater	inland water with no measurable salt content
geographical considerations	the desired distance of the site from the dredging areas and preferred geometry of the site; a transport distance of 25 nm was used as the maximum to minimize transportation cost; a near-circular or elliptical shape yields largest surface area per unit length of the dikes and was therefore preferred
geophysical data	includes site bathymetry (water depth), identification of existing and/or historic dredged material placement sites, identification of potential UXO, and site sub-bottom profiles
geotechnical considerations	include consolidation, permeability, and shear strength of the foundation material which dictates to a large extent the dike design at the site and the site capacity
geotechnical data	include index property tests (water content, Atterberg limits, specific gravity, and grain size distribution); probing/borings; in-situ vane shear tests, CPT, and consolidation, permeability, and shear strength tests
global positioning system	system that provides an extremely accurate position (usually within 10m); data is derived using radio frequency signals from satellites orbiting the earth

gyre circulation	movement of water in a circular pattern
habitat	the specific area or environment in which a particular type of plant or animal lives; an organism's habitat provides all of the basic requirements for the maintenance of life
hectares	a metric unit of area; one hectare = 2.47 acres
high tide (high water)	maximum elevation reached by each rising tide
higher high water	the higher of the two high waters of any tidal day
hindcasting	the use of historic synoptic wind charts to calculate characteristics of waves that occurred at some time past
human-environment parameter	water quality; salinity; hydrodynamic effects; sediment quality; benthic community and habitat; recreational fishery; commercial fish and shellfish; finfish spawning and rearing habitat; larval transport; submerged aquatic vegetation and shallow-water habitat; waterfowl use; tidal wetlands; terrestrial habitat and wildlife; rare, threatened, and endangered species; recreational value; historical resources; aesthetics and noise; fossil shell mining; UXO and CERCLA liability; and navigation
hurricane	an intense tropical cyclone in which winds tend to spiral inward toward a core of low pressure; maximum surface wind velocities equal or exceed 75 mph for several minutes or longer at some point
hydrodynamics	dynamics of fluids in motion; includes physical forces from waves, tides, and currents
hypoxic	waters with dissolved oxygen concentrations < 1 mg/l
in-situ	resources or measurements taken "in place" in contrast to resources or measurements in a laboratory
infaunal organisms	living within the bottom sediments, usually within burrows

initial site construction costs	cost of construction of dikes to the desired initial elevation; dike stabilization costs (armor, underlayer, & toe protection); installation of spillways/outlet structures; & site infrastructure
inner harbor channels	include Northwest Channel, East Channel, Ferry Bar Channel, Fort McHenry Channel, Curtis Bay Channel, and Brewerton Channel
invertebrates	any animal lacking a backbone
larvae	a young stage of an organism that differs appreciably from its form as an adult
lift thickness	thickness of placement of dredged material
liquid limit	the water content at which soil begins to flow and behave as a liquid
longshore current	a current moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline
low tide (low water)	minimum elevation reached by each falling tide
lower low water	the lower of the two low waters of any tidal day
mammals	a class of vertebrates characterized by the presence of hair, the ability to bear live young, and the ability to produce milk
marine	species that inhabit and breed in ocean waters that exceed 30 ppt
maximum turbidity zone	an area of the Upper Chesapeake Bay
mean (higher high, high, low, lower low) water	average height of the (higher high, high, low, lower low) waters over a 19-year period
mesohaline	moderately brackish water with a salinity of 5-18 ppt; upper mesohaline is 10-18 ppt; lower mesohaline is 5-10 ppt
micron	metric unit of measure equal to 10^{-6} m

nearshore zone	an indefinite zone extending seaward from the shoreline well beyond the breaker zone
neo-tropical migrants	transient birds originating from Southern Mexico, Central or South America, or the West Indies
nephelometric turbidity units	units of turbidity used to measure the size and concentration of particles in a liquid by analysis of light transmitted through or reflected by the liquid
NOEL	no observed effect level; toxicological term that refers to the concentration of a parameter for which no adverse effect has been observed
normally consolidated	soil that has never experienced loads greater than current loads
nursery habitat	areas used by larval and juvenile fishes; in estuaries, shallow-water oligohaline and low-mesohaline areas are most utilized
nutrients	compounds or elements required for growth and reproduction (i.e., carbon, nitrogen, oxygen, phosphorus)
offshore	the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the continental shelf
offshore/onshore current	a current directed offshore/onshore
oligohaline	slightly brackish water with a salinity of 0.5 to 5 ppt
omnivore	organism that feeds on both plant and animal matter
outer harbor channels	C&D Canal and Approach Channel, Tolchester Channel, Swan Point Channel, Brewerton Extension Channel, Craighill Upper Range Channel, Craighill Channel, and Craighill Entrance Channel
palustrine wetland	non tidal wetland dominated by trees, shrubs, persistent emergents, or emergent mosses and lichens

PEL	probable effect level; toxicological term that refers to the concentration of a parameter at which an adverse toxic effect is probable
pH	a logarithmic index for hydrogen concentration in aqueous solution; used as a measure of acidity
phytoplankton	small, floating plant life in an aquatic system; planktonic plants (e.g., algae)
plastic limit	the water content at which the soil begins to crumble when rolled into a thread about 3 mm in diameter
plasticity index	difference between liquid limit and plastic limit
ponar grab sampler	a piece of sampling equipment that consists of a jaw-like apparatus that closes on contact with the bottom substrate; used to obtain a quantifiable sample of the bottom sediment
pre-consolidation pressure	maximum pressure that the soil has been consolidated under, including the geologic past
present worth costs	site development costs and dredging/transport/placement costs over the operational life of the site, discounted based on an annual borrowing rate
pycnocline	layer of water that exhibits a rapid change in density
remediation	act of providing a correction, remedy, or solution
reptiles	cold-blooded, egg-laying, vertebrates having a scaly or plated outer covering (e.g., snakes, lizards, turtles)
revetment	a facing of stone, concrete, or other material, built to protect erosion by wave action or currents
rookery	a breeding and nesting area
runoff	rainfall not absorbed by soil, often includes particulate materials and contaminants

salinity	the measurement of dissolved salts in water; the number of grams (parts) of dissolved salts in 1,000 grams (parts) of water, usually expressed in parts per thousand (ppt)
salt wedge	layer of high salinity bottom water that moves up the bay; the exact location and extent depend on freshwater surface flows moving down the bay; the up-bay movement of the salt wedge is important for transport of larval and juvenile finfish and crabs
sand	sediment grain size ranging from 62 microns (0.062 mm) to 2 mm in diameter
seas	waves caused by wind at the place and time of observation
secchi disk	a flat black and white disk attached to a line that is lowered into the water; the depth at which the secchi disappears and the depth at which the secchi reappears is averaged to provide a secchi depth; secchi depth is used as a measure of water clarity
sediment	particulate material that accumulates on the bottom of a water body; silt, clay, sand, or organic materials
semidiurnal tide	a tide with two high and two low waters in a tidal day
sessile	non-motile
shallow water	water of such depth that surface waves are noticeably affect by bottom topography
shear strength	resistance to deformation by continuous shear displacement of soil particle
shellfish	aquatic organisms that have a shell or shell-like outer covering (i.e., oysters, clams)
shoal	a submerged sand bar or sand bank
shore	the narrow strip of land in immediate contact with the sea

shoreline	the intersection of a specified plane of water with the shore or beach (typically taken as mean high water or mean higher high water)
side-scan profile	an underwater remote sensing technique in which sound pulses are sent to either side of a ships track. Returning echos from the water column and seafloor are printed to produce a coherent picture of the bottom
silt	sediment particles intermediate in size between sands and clays, ranging from 2 microns (0.002 mm) to 63 microns (0.063 mm) in diameter
site development costs	the costs of construction and operation of the site, and including initial site construction costs, annual costs, and dike raising costs
site-specific coastal data	wave, current,temperature,conductivity,and depth information
soil classification	an arbitrary division of a continuous scale of grain sizes
soil strata	a horizontal layer of soil
spawning habitat	areas where eggs and/or sperm are released into the water
spillway	a channel that is designed for the overflow of water
standard penetration resistance	number of blows of 140 lb. hammer falling 30 in. required to drive a 2" outer diameter split barrel (spoon) 12 inches into the soil
storm surge	a rise above normal water level on the open coast due to the action of wind stress on the water surface or atmospheric pressure differentials associated with storm events
stratification	division of an aquatic community into distinguishable vertical layers on the basis of temperature light penetration, salinity, or dissolved oxygen concentrations

sub-bottom profile	an underwater remote sensing technique in which sound pulses are directed downward towards the bottom; echos are returned from the seafloor and from different sediment layers below the bottom
submerged aquatic vegetation(SAV)	underwater aquatic plants
substrate	the bottom surface of a body of water on/in which benthic organisms live (e.g., clay, sand, mud, oyster shell)
surf zone	the area of breaking waves
swell	wind-generated waves that travel out of their generating area
taxon	a group of organisms sharing common characteristics and constituting one of the categories of taxonomic classification
terrestrial	of or related to earth or land
tidal day	the time of the rotation of the earth with respect to the moon, or the interval between two successive upper transits of the moon over the meridian of a place, approximately 24.84 solar days
tidal datum	the plane or level from which soundings, elevations, or tide heights are measured
tidal range	the difference in height between consecutive high and low waters
topography	the configuration of a surface, including its relief and the positions of its streams, roads, buildings, etc.
total site costs	site development costs and dredging/transport and placement costs over the operational life of the sites
total alternative costs	site development costs plus maintenance dredging costs for the operational life of the site
tropical storm	a tropical cyclone with maximum winds less than 75 mph

underlayer	a layer of small stones that provide protection from filtering
Virginia channels	Rappahannock Shoal Channel, York Spit Channel, and Cape Henry Channel
water content	ratio of the weight of water to the weight of dry soil in the sample
wave climate	the combination of waves of different heights, periods, and directions
wave height	the vertical distance between a crest and the preceding trough
wave crest	the highest point on a wave
wave direction	the direction from which a wave approaches
wave length	the horizontal distance between similar points on two successive waves measured perpendicular to the wave crests
wave period	the time for a wave crest to traverse a distance equal to one wave length
wedge failure	slope failure that has the shape of a wedge rather than a circle
wind waves	waves formed and built up by the wind

APPENDIX D
LIST OF PREPARERS

This report was prepared by a joint effort between EA Engineering, Science & Technology, Inc. (EA), Earth Engineering & Sciences, Inc (E2Si), Gahagan & Bryant Associates, Inc. (GBA), and Moffatt & Nichol Engineers (M&N).

EA prepared Chapter 7 (Environmental Investigation), and provided review comments on other sections of the report. EA also provided the color figures for the text.

E2Si prepared Chapter 4 (Geotechnical Investigation)and provided review comments on other sections of the report.

GBA provided overall coordination for the report preparation and prepared Chapters 1 (Introduction), 2 (Site Mapping and GIS), 3 (General Site Descriptions), 6 (Dredging & Site Engineering), and Appendix-A (Base Maps and Dike Cross-Sections).

M&N prepared Chapter 5 (Coastal Engineering Investigation)and provided review comments on other sections of the report. M&N also provided the title sheet for the report.

The Maryland Geological Survey (MGS) prepared Appendix-B (Geophysical Investigation Report).

The Executive Summary and Chapter 8 (Summary and Conclusions) were modified from sections of the Report to the Maryland General Assembly on the Prefeasibility Study for Upper Bay Island Placement Sites. This report was prepared for the MPA by Laura Ost.

The four consultants jointly prepared the list of symbols and acronyms, the list of references, the glossary, and the list of preparers.

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